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Women in Science: Stories from the Margins

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WOMEN IN SCIENCE: STORIES FROM THE MARGINS

by

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(Under the Direction of John Weaver)

ABSTRACT

Women are significantly underrepresented in the hard sciences and engineering. While the number of women seeking degrees in these fields has increased in the last forty years, a substantial gap still exists between the sexes. The purpose of this dissertation is to examine one area of influence on career choice- the curriculum.

Women scientists are underrepresented in the school curriculum. This dissertation examines the discourse of curriculum and the role it has in the gendering of the field of science. The nature of the development of a curriculum lends itself to the practice of exclusion. The construction of curriculum is a human act. As a human act, the development of the curriculum is guided by choices made by those in positions of power. In examining the curriculum, one should ask whose knowledge is being represented? A critical analysis of the official curriculum and the textbooks which drive it reveals that women are steered away from participating in the hard sciences and engineering due to the gendering of these fields.

An examination of three women's lives- Maria Mitchell, Ellen Swallow Richards, and Rachel Carson- expose the potential impact of including women in textbooks and the official curriculum. The names Rachel Carson, Ellen Richards, and Maria Mitchell

should not disappear from our lexicon. The struggles these women overcame in order to advance our knowledge of the world can inform the next generation of students on the "lines of flight" which exist despite the oppressive nature of the culture of science (Reynolds & Webber, 2004).

INDEX WORDS: Curriculum studies, Feminist science studies, Women in science

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DEDICATION

This work is dedicated to my husband, Sean, and my daughters, Katie and Mallory. This work would not have been possible without your love and support throughout this entire journey. Thank you for being my biggest supporters and inspiration.

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TABLE OF CONTENTS

CHAPTER 1

VOICES FROM THE MARGINS

Ask someone to name a famous female scientist and chances are they will say Marie Curie. The general population would have difficulty naming many other females that they know in the field of science while being able to list numerous men. Where does this belief originate- school curriculum, popular media, science history books? Could so many mediums have it wrong?

> We say 'we are what we know.' But we are also what we don't know about ourselves-our history, our culture-is distorted by deletions and denials, then our identity-as individuals, as Americans-is distorted (Pinar, 1994, p.246).

What the science curriculum has taught us about the history of science has been distorted. It has influenced what individuals learn about the history of science through deletions and denials. Carefully chosen male figures have been granted the glory of recognition. This has been cruel to the memory of many women contributors to the field. Our perceptions of who has been involved in science has been distorted. These distortions are motivated by gender bias.

The field of curriculum studies has long examined the relationship between power and knowledge. In his groundbreaking work, *Pedagogy of the Oppressed*, Paulo Freire clearly articulated the connection between the control of knowledge and power. To Freire, the control of knowledge, via the educational system, placed power in the hands of a select group, the oppressors. "The capability of banking education to minimize or annul the students' creative power and to stimulate their credulity serves the interest of the

oppressors, who care neither to have the world revealed nor to see it transformed" (Freire, 1970, p. 72). In the vast wake left by Freire, numerous scholars- Henri Giroux, Peter McLaren, bell hooks, Maxine Greene- followed. All, in a unique way, questioned the construction and control of the curriculum.

The nature of the development of a curriculum lends itself to the practice of exclusion. The construction of curriculum is a human act. As a human act, the development of the curriculum is guided by choices made by those in positions of power. In examining the curriculum one should ask whose knowledge is being represented? Who has influenced its creation? As the search for the Truth, the fields of science have often been ignored as realms subject to manipulation by the powerful. Unfortunately, this thinking is flawed.

In John Gribbin's (2002) seminal work, *The Scientists*, the author attempts to trace the history of Western science through the stories of great inventors. The names that appear in the text- Copernicus, Galileo, Hooke, Plank, Einstein, Bohr, Paulding- form the pantheon of science. As I turn each page, one question forms in my mind. Where are the women? Tucked near the conclusion of the work one finds the tale of Marie Curie. Gribbin's (2002) opens Curie's story with the following paragraph.

> It is Marie Curie's name that is most strongly linked in the popular mind with the early investigation of radioactivity. This is partly because her role really was important, partly because she was a woman, and by providing one of the few role models for girls in science was assured of good press, and partly because of the difficult conditions used which she worked, adding an element of romance to the story. This even seems to have affected the Nobel committee, which managed to give her the prize twice for essentially the same work. (p. 497)

By attaching Curie's fame to her sex and not solely to her work, Gribbin simultaneously celebrates and belittles the work of the French chemist. Her work, the nature of radioactivity, does not make her worthy of remembering. The fact that a female could complete such work and its value as good press makes its worthy of being included in the history of science.

While one may be angered by the stigma placed on Curie's work, Stephen Jay Gould, famed evolutionary biologist, paleontologist, and historian of science, points out a greater travesty committed against the female scientists of the past- oblivion.

> The keeper of official records had used the primary device of excommunicators, anathematizers, and ostracizers throughout history: there is a fate far worse than death or the rack, and its name is oblivion- not the acceptable fading of an honored life that passes from general memory as historical records degrade but the terror of unpersoning, of being present (either in life of immediate memory) but bypassed as though nonexistent. (Gould, 1997, p. 27)

Marie Curie's story has survived. Countless others have been allowed to fade from memory. Their labors have advanced the sciences, but the names have been allowed to pass from the historical texts. They were not awarded the crown of recognition.

What has been the impact of this bypassing? What are the repercussions of the unpersoning to the future of women in science? What can be done to correct the passage into oblivion?

The names Rachel Carson, Ellen Richards, and Maria Mitchell should not disappear from our lexicon. The struggles these women overcame in order to advance our knowledge of the world can inform the next generation of students on the "lines of flight"

which exist despite the oppressive nature of the culture of science (Reynolds & Webber, 2004). Over the course of this text, I hope to illuminate these women's stories and to show their importance in overcoming obstacles that face women's full participation in the sciences. I believe that shedding light on the past will serve as beacon for future women who wish to become explorers of the world's natural phenomenon. As I look back over the course of my life, I wonder what might have been. What might have been if I had known the powerful stories of Carson, Richards, Mitchell when I was a child? What path would I have taken if I had known of their heroic tales?

In the science curriculum, regardless of the questions, the answers are almost always what a man in science has accomplished. "Intelligence is made more narrow, and thus undermined, when it is reduced to answers to other people's questions, when it is only a means to achieve a preordained goal" (Pinar, 1994, p.243). The history of science has demonstrated that its preordained goal is to present what men have accomplished in science to the detriment of women in the field. The goal of the science curriculum is to reflect that the important discoveries of science have been accomplished by white males. It has determined what was most important and whom will be credited with its honor. This unfair portrayal has miseducated generations of students. An example of this type of miseducation was noted in Woodson's *The Mis-education of the Negro.*

> From the teaching of science the Negro was likewise eliminated. The beginnings of science in various parts of the Orient were mentioned, but the African's early advancement in this field was omitted. Students were not told that ancient Africans of the interior knew sufficient science to concoct poisons for

> arrowheads, to mix durable colors for paintings, to extract metals from nature and refine them for development in the industrial arts (1990, p.18).

The elimination of minorities from the curriculum has dominated our schools and in the process miseducated students into believing that everything important has been accomplished by white males.

According to Fissell (1999), " In 1874 at Harvard Medical School, a question for the annual Boylston Prize essay competition was 'Do women require mental and bodily rest during menstruation and to what extent?'" (p. 246). This topic was spawned into scientific consideration the previous year by Harvard professor, Dr. Edward Clarke who published *Sex in Education, or a Fair Chance for Girls*. In this work, he explained that a woman's body was not capable of handling the rigors of higher education. To subject the female anatomy to such rigors would threaten their reproductive health and could lead to their becoming sterile. In his work, Dr. Clarke cited cases studies proving his claim. A Harvard professor making such claims made many begin to question the medical safety of women in higher education. Of that time, M. Carey Thomas, the president of Bryn Mawr College, stated, "We did not know when we began whether women's health could stand the strain of education. We were haunted, in those days, by the clanging chains of that gloomy little specter, Dr. Edward H. Clarke's *Sex in Education*" (Thomas in Fissell, 1999, p. 246).

This unbelievable claim was echoed throughout college campuses for years. Biases against women students were rampant and they stemmed from one man who used his position of power and prestige to inflict women with a medical cause to justify his gender bias. While the belief that higher education would inflict physical harm on the female

anatomy has all but disappeared, the presumption that the genetics of sex informs one's ability to perform scientific thought remains firmly embedded in the American culture.

On January 15, 2005, Lawrence H. Summers, the President of Harvard University, former Chief Economist for the World Bank, and Secretary of the Treasury from 1999 to 2001, delivered the following comments at the National Bureau of Economic Research's Conference on Diversifying the Science and Engineering Workforce:

> I think one has to recognize what is present is what I would call the combination of, and here, I'm focusing on something that would seek to answer the question of why is the pattern different in science and engineering, and why is the representation even lower and more problematic in science and engineering than it is in other fields. And here, you can get a fair distance, it seems to me, looking at a relatively simple hypothesis. It does appear that on many, many different human attributes-height, weight, propensity for criminality, overall IQ, mathematical ability, scientific ability-there is relatively clear evidence that whatever the difference in means-which can be debated-there is a difference in the standard deviation, and variability of a male and a female population. (Summers, 2005, p. 1)

While Summers' comments caused an uproar as evidenced by the lack of confidence vote by Harvard's Faculty of Arts and Sciences, the remarks are not outside of the norm. The belief that the study of the 'hard' sciences is the realm of men persists. Women are still being viewed as the lesser species and not as capable as men. This kind of gender bias now has become more sophisticated in its deception by attempting to use science to explain why women are not as capable as men. This mindset is currently influencing

science and how women are included or excluded from it. While Summers' statement may find many supporters in the general population, innate differences in ability have not been found to exist. The lack of women pursuing careers in science, technology, engineering, and mathematics can be traced to gender expectations.

The belief is that women are wired differently and just don't get science. These socially constructed biases claim to be based on genetic predetermination. In the past, this mindset led to formal exclusion from the educational and research institutions which support scientific endeavors (Whitehouse, 2004). In recent years, formal barriers have been removed, in large part due to federal legislation such as Title IX of the Education Amendments of 1972. Title IX states:

> No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance. (United States Department of Labor, 1972, p. 1)

Title IX forced those colleges and universities which accept federal funding to create open admissions policies in regard to one's sex. Additionally, the law forbids the use of one's sex in employment decisions at research institutions receiving federal monies. Since federal funds flow into most institutions of higher learning and large research entities, Title IX was effective in removing formal barriers to women's engagement in science.

While the formal barriers have crumbled, informal hurdles to the full participation of females in science and engineering still exist. Among the tallest of informal hurdles to female participation in the science and engineering fields is the impact of gender identity.

While our sex is biologically determined by the chromosomes one inherits, gender is a social construct. “The critical theoretical concept was that of ‘gender’, introduced as a way of distinguishing the social constitution of masculine and feminine from the biological categories of male and female” (Keller & Longino, 1996, p. 2). Gender is negotiable and subject to change due to shifts in societal and cultural roles. “In other words, “woman” is a social construct to which little girls are taught to aspire. For, inevitably, we see ourselves as others see us, and our visions are guided by the available options” (Hubbard, Henifin, & Fried, 1982, p. 6). The social construction of woman is what leads to the belief that females are innately more caring, nurturing, and less capable of performing formal scientific exploration.

By the time a woman has reached adulthood, she has been bombarded with images that steer her away from a career in the science and engineering fields.

> Gender difference is the most ancient, most universal, and most powerful origin of many morally valued conceptualizations of everything else in the world around us. As far back in history as we can see, we have organized our social and natural worlds in terms of gender meanings within which historically specific racial, class, and cultural institutions and meanings have been constructed. (Harding, 1986, p. 17)

The internalized devaluation of self (and the group to which one belongs) is reinforced by threats or discriminatory experiences. Psychologically, these experiences come to represent the societal predictions of what women can expect, or who we are, and what we deserve. A sense of unworthiness may thus become part of the organizing nucleus of

women's self-esteem and may contribute to the unconscious background of other experiences. (Hamilton, 1989, 39-40)

The impact of the assault leads to significant changes in girls' perceptions of their ability to succeed in hard science fields and correspondingly reduces their interest in pursuing a career in biology, chemistry, physics, or engineering.

> Generally, in elementary school, boys and girls do not vary significantly in math/science ability; confidence, or interest; however many math/science gender differences are evident by the end of high school, with the junior high-school years probably being transition years for most youth, but particularly girls. (Potier, 2004, p. 1)

Interest in the sciences quickly wanes as the typical female passes through adolescence. During this time period, the images and conversations in the public domain steer her away from the fields defined as male.

For, is it not true, males are more capable of performing scientific thought? It has long been argued that this is true. According to Keller (1985),

> Most culturally validated intellectual and creative endeavors have, after all, historically been the domain of men. Few of these endeavors, however, bear so unmistakably the connotation of masculine in the very nature of the activity. To both scientist and their public, scientific thought is male thought, in ways that painting and writing- also performed largely by men- have never been. (p. 76)

A man in a white coat performing detailed manipulations in a laboratory filled with complex mechanisms. This is the image that quickly forms when the word scientist is

mentioned (Finson, 2002). It has become ingrained into our culture. We have a "masculine image of science" (Kelly, 1982, p. 497).

The masculine imaging is part of the traditioning which protects the status quo. Traditioning builds a barrier to change by providing a historical account that supports the current state. According to Doll (2000), "Traditioning is by nature uncritical, unquestioning, inauthentic, and exclusive. It seeks to preserve a pure past by building a very large mausoleum for the housing of its myth" (p. 10). The "pure past" of science contains the stories of male heroes who changed the face of our planet but the tales of women have been conveniently allowed to fade. It is believed that this history should not be questioned, as it is a reporting of factual events and not subject to manipulation.

The exclusion of women from the fields of science operates to protect that which is masculine.

> What it means to be a man is, in part, to share in masculine control of women. Men's individual and collective need to preserve and maintain a defensive gender identity appears as an obstacle to women's accumulating status within science. (Harding, 1986, p. 64)

Defense of the laboratory from the incursion of women becomes a defense of manhood. Women's intrusion into the laboratory is an assault on the special nature of man. As a field of great import, due to its great political and economic impact, science has been declared the province of man (Keller, 1996; Kohlstedt, 1999; Kourney, 2002). It was believed that men have the superior ability to perform science activities so the laboratory was a domain that women were historically not accepted.

> Those of us who are feminists have been struck by the interlocking character of knowledge and power in the sciences. Women have been excluded from the practice of science, even as scientific inquiry gets described both as a masculine activity and as demonstrating women's unsuitability to engage in it, whether because of our allegedly deficient mathematical abilities or our insufficient independence (Longino, 2002, p. 310).

The belief in women's innate inability to perform in science has been used to justify their exclusion from the field. This belief has allowed men to dominate in the field.

The belief that females' abilities are limited in scope is widespread. "Assumptions that women's biology, moral reason, intelligence, contributions to human evolution, or to history or present-day social relations are inferior to men's are not idiosyncratically held beliefs of individuals but widespread assumptions of entire cultures" (Harding, 1998, p. 135). While strides have been made towards viewing males and females as equals, in the sciences, imbalances still exist.

In 1957, Mead and Metraux examined the essays of 35,000 high school students on their beliefs about the characteristics of scientists.

> A man who wears a white coat and works in a laboratory. He is elderly and middle aged and wears glasses… he may wear a beard… he is surrounded by equipment: test tubes, Bunsen burners, flasks and bottles, a jungle gym of blown glass tubes and weird machines with dials… he writes neatly in black notebooks… his work may be dangerous … he is always reading a book. (p. 2)

The 1950's were dominated by the belief that the rightful place of the woman was in the home and not in the laboratory. Surely, as the decades have passed and women have

moved towards equality with men, this mindset has changed. Unfortunately, recent studies have found this not to be the case. Beth Potier, a Harvard-based researcher, found the following in her 2004 study.

> Ask most people to pull up a mental image of a physicist, and they'll likely present a wild-haired amalgam of Albert Einstein and Bill Gates wearing Buddy Holly glasses, a lab coat, and yesterday's lunch on his shirt. After all, it hardly matters what you look like if you're doing great science, right? (p. 1).

The image persists and remains a formidable barrier to the full inclusion of women in multiple fields of science. The perpetuation of this image of men being scientists is encouraged due to the lack of significant female representation in the various forms of media and textbooks. The stereotype and belief in the 'fathers of science' permeate the majority of historical books in print. A trip to a local bookstore chain will show an individual the limited amount of books written by or about women in science in the mainstream arena. In order to find books about women in science, one must seek alternate sources. Many times these women's stories are found to be out of print or their work is found only in the children's literature section. This small sector of writers who are fighting for these women's stories to not be forgotten are denied the recognition deserved in the mainstream. It is this lack of exposure that is contributing to the perpetuation of the male dominated science image.

A brief review of position statements released by professional organizations serve as an additional reminder that gender inequality is alive and well in science education. In 2003, the National Science Teachers Association found the need to release a position statement on gender equity in science education. "Gender equity means ensuring that all

boys and all girls- regardless of age, cultural or ethnic background, or disabilities- have the support they need to become successful science students and feel respected and challenged"(National Science Teacher Association, 2003). The association found the treatment of males and females in the sciences were still far from equal. In it's *General Position Statement on the Application of Title IX to Science, Technology, Engineering, and Mathematics Fields,* The Society of Women Engineers (2006) found, "While most educational institutions do sign pro forma statements that assure federal granting agencies that they comply with Title IX, many go no further in discharging the obligations set forth in the implementing regulations" (p. 4). Additionally, the society's position paper reiterated the need for interventions to reduce social and psychological barriers to women's involvement in science, technology, engineering, and mathematics.

Females have made significant strides towards equality in the educational and employment arenas in the United States over the last thirty years. Unfortunately, the gains have not been equally distributed among the fields of study.

> [I]n school and in college, females are now doing as well as or better than males on many of the indicators of educational attainment, and that large gaps in educational attainment that once existed between men and women have in most cases been eliminated and, in others, have significantly decreased. Nevertheless, women continue to lag behind males in mathematics and science achievement in high school and are far less likely to major in these fields in college. (International Center for Educational Statistics, 2004, p. 12)

While the number of women enrolled in science and engineering graduate programs in the United States has grown substantially in recent years (from 162,011 in 1997 to

202,020 in 2004), their ranks are far surpassed by the number of males enrolled (274,311 in 2004). Upon a deeper examination of the statistics, the numbers are even more grim. The National Science Foundation statistics include the social sciences (economics, anthropology, sociology, and political science) and psychology when reporting participation rates in science and engineering fields. By performing this statistical slight of hand, the National Science Foundation bolstered the number of women reported entering science fields and therefore were able to claim to have made significant headway towards the accomplishment of one of its major goals- increasing the numbers of underrepresented populations in science. Social science and psychology graduate programs have seen explosive growth in the number of female students enrolled and in recent years have surpassed the number of males. The number of females enrolled in graduate programs in chemistry, physics, mathematics, and engineering has remained pathetically low.

Oslo, Norway. Three scientists are giving their acceptance speech at the 1962 Nobel Prize ceremony. Watson, Crick, and Wilkins, have made one of the most important discoveries in the field of genetics, the structure of DNA. What many do not know is that they are accepting the award under false pretences. Betrayers all, they are taking full credit for the discovery of the map of human structure and excluding a major contributor, Rosalind Franklin.

Franklin, a molecular biologist, perfected the art and science of X-ray diffraction. It is this talent that led her to be able to create images of the DNA double helix. Wilkins, a fellow research scientist at King's College in London, *acquired* one of Franklin's images and presented the plate to Watson. "The instant Watson saw the picture, his mouth fell

open and his pulse began to race" (McGrayne, 1998, p.319). Viewing this photograph led to Watson and Crick's finalization of the model for DNA.

Franklin's development and use of the techniques to create images of the DNA molecule was foundational in the explanation of the structure of the hereditary material. Wilkins, only a minor contributor to the field of molecular biology before presenting the startling picture to Watson, was catapulted into the spotlight and accepted one-third of the Nobel Prize for Medicine. Franklin's name was mentioned only once at the ceremony. On the basis of what the three winners said in their Nobel Prize lectures, no one would have known that Franklin had contributed to their triumph. Their three Nobel lectures cite ninety-eight references, none of them Franklin's. Only Wilkins included her in his acknowledgments (McGrayne, 1998, p.329).

> The devaluation of any work known to have been done by women, the exclusion of women from men's informational networks, the obstacles put in the path of woman's attempts to obtain safe and reliable mentors (and, later, to be perceived as mentors themselves)- these and other informal discriminatory tactics give us increased appreciation for those women who have managed to persist. (Harding, 1991, p. 29)

In the devaluation of Frankin's work and subsequent erasing of her story from the history of DNA, science has successfully created a tale with false victors. There are numerous books on Franklin's story however, they are not part of the accepted science history included in science textbooks. Science has successfully written many women out of existence. "Erasing lived experience, erasing human subjectivities in school life, endangers students and teachers alike because we have no sense of who we are. This

absenting erases our histories, memories, and our situatedness" (Morris, 2001, pp. 1-2). This erasing of lived experience influences how girls view their place in science. If women are excluded from the scientific record, replaced by men, then the very sense of who women are is damaged.

Mainstream science creates a reality of what it chooses to accept. That accepted science mythmaking is a strong force holding on to its male domination. The nature of what is accepted as science history is embedded in myth.

> Mythos is the knowledge and ways of knowing associated with cultural myth and folklore, passed down from generation to generation and never questioned, a knowledge and knowing that take things for granted as the way they naturally should be (Carlson, 2002, p.6-7).

The stories of science have been influenced by mythos. It has created a history as it wishes it to be-that everything important done in science has been accomplished by men. Despite the numerous attempts to right the record regarding Franklin in the history of genetics she remains excluded from the mainstream acceptance, she has been replaced by the fathers of genetics: Watson and Crick. It appears that science history is destined to perpetuate the myths of the past.

The general populace tends to view science and history as fact. Science and its historians have determined that nearly all important scientific achievements have been accomplished by men.

> Traditionally power has been equated with knowledge. 'Knowledge is power,' Bacon asserted. But this equation implied that knowledge requires an undistorted view of how reality is. Knowledge is constructed as a representation of the real, or

> reality as it 'really' is. For poststructuralist, discourse, which includes knowledge, does not represent reality. For poststructuralist, discourse *constructs* reality. (Pinar, Reynolds, Slattery, & Taubman, 1995, p.463)

The discourse of science has crowned men as the victors of science and this has constructed what we know. These stories of the great fathers of science have distorted our view of women in the history of science. Science creates knowledge. If women are not acknowledged then they must have played an insignificant role in history. Any contrary stories that challenge the male centered science are excluded. This is how science constructs our scientific knowledge. "When we teach science, we are not teaching our students about the 'real' nature of things, we are conveying to them narratives about what Western culture has decided the nature of things is" (Whitehouse, 2004, p.1). Science knowledge is as much about what it teaches as what it does not. Omission of women in science history teaches us to think about women as the lesser gender. It devalues those who it excludes and those who are being taught. This practice drives the miseducation of students to believe that what they are learning is the one true history. Science: the ultimate purveyor of truth.

> It is recognized that the conditions of truth, in other words, the rules of the game of science, are immanent in that game, that they can only be established within the bonds of a debate that is already scientific in nature, and that there is no other proof that the rules are good than the consensus extended to them by the experts. (Lyotard, 2002, p. 29)

This manipulation of truth and the rules of science has contributed to the position of women in the history of science. History has not reflected the importance of women and

their contributions to the field of science. The history of science has been cruel to the memory of many women who contributed to the field in monumental ways. Feminist science scholars are attempting to rectify these oversights. They are finally shedding light on the corners of science history where women have been pushed.

Without an accurate portrayal of females in the history of science, we present distortions and misconceptions that have a profound affect on what will come.

> For women who have managed to obtain a foothold within the world of science, the situation is particularly fraught. Because they are 'inside," they have everything to lose by a demarcation along the lines of sex that has historically worked to exclude them. (Morse, 1995, p. 13)

The school curriculum mirrors the biases that have played a part in the historical record. According to Weaver (2004), "Curriculum planners and designers also transform the narratives we use to tell our curriculum stories. They take the metaphoric and the narrative and bury them beneath a surface of statistical language and assumed cold, hard facts" (p. 26). Women have been successfully marginalized in the history of science. Their contributions have been ignored, devalued, and in many cases stricken from the record. In examining science reforms one must look beyond the ideas of providing equal access to girls in the science classroom and begin to look at how the curriculum itself is contributing to the beliefs about women in science. The women who have been marginalized in the history of science will tell the tale that women are not transforming in our present time to become more interested in the field, but they have in fact always been in the field. By using the stories of these individuals and their contributions, girls may

identify with the field. More than a change in curriculum, a change in mindset must take place.

At the elementary school level, males and females self-report high levels of interest and ability in science. Additionally, in these earlier grades, females' standardized test scores in the area of science equal those of their male counterparts. As time passes, discrepancies begin to manifest between the sexes. As females' transition to middle and high schools, females' interest and test scores begin to decline and become significantly lower than their male peers.

> Briefly put, there are social and cultural forces at work to create differences in experiences and expectations for boys and girls, and to communicate to children what behaviors are considered to be 'sex-appropriate'. Socialization factors range from effects of role modeling, society's expectations of children, to differential life experiences. These, in turn, affect attitude and achievement. (Mahlab, 1998, p. 35)

It appears that only women whose fame is so significant that it cannot be ignored are included in the historical records of science before the last half century. Only women such as Marie Curie were contained in the historical record during this period. Her recognition may have been influenced by the fact that her scientific discoveries were validated by a male, Pierre Curie, her husband, who was a talented scientist and scion of a powerful family. Others have even written that it was actually her husband's work that she was given credit for. Even a famous scientist like Marie Curie is not immune to the devaluing of women in science. By expanding my knowledge of women in science, I realize I had been influenced by the popular stories of science to believe that everything

important has been accomplished by men. Examples of women scientists were not included in my education beyond that of Marie Curie.

In examining science textbooks it could be assumed that while women may have been included in science, they did not accomplish anything of importance, or if a part of a discovery, it was a matter of pure luck. As Mahlab (1998) found:

> Even when recognized, women's achievement is characteristically acknowledged within the context of serendipity rather than ability. What is skill for the male is considered luck for the female. This characterization severely undermines women's confidence and fosters an internal belief that we cannot trust our successes. (p. 30)

It is the discrediting of women scientists and the fabrication of history that has led to this misrepresentation.

One such undermining of women in science is when science textbooks practice an 'inclusion' technique that proclaims to be giving them an equal place in science. This is when women's stories are used as a sidebar in the back of a chapter in the science text or in a narrative about a woman's contribution to science separate from the content material.

> Cosmetic bias offers an "illusion of equity" to teachers and students who may casually flip the pages of a textbook. Beyond the attractive covers, photos, or posters that prominently feature all members of diverse groups, bias persists. Examples include a science textbook that features a glossy pullout of female scientists, but precious little narrative of the scientific contributions of women. (Zittleman & Sadker, 2007, p. 6)

This practice of sidebar inclusion is commonly observed in science textbooks. The illusion is that women are being given equal coverage but it is actually an insult to

display their stories unworthy of inclusion into the curriculum material. This practice is also displayed in the 'Famous Women in History Month' often used in schools. This proclaims to award these women for the sake of being women not for their accomplishments in history. Stories determined unworthy of inclusion in the everyday classroom material, given merely a month of the school year for recognition. The message sent to students is that women did not make important enough contributions to be included in the text and that they only deserve glory for being a female who participated in science.

The history of science is overwhelmingly male. The portrayal of women in its history has been unfair to the memory of many great women and their contributions to the field. In examining the individual stories and the significance of these individuals impact on the field, it is amazing that they are widely unknown to the general population. Years of reading popular science books exposed me to numerous stories of the great men of science and hardly any recognition of women. My research into the field of science studies has forever changed my viewpoint of women in science. In examining the stories of women in science I have begun to question my earlier miseducation in the school curriculum and in mainstream science mediums. My intrigue at the stories of these women has changed my view of the importance of women in science and increased my awareness of the magnitude of the exclusion that has occurred. I believe these women's stories could change a mindset and years of miseducation in others as it has myself. The women whom I have chosen to examine are both amazing in their impact and in the significance of their lack of inclusion in the science curriculum. Their stories are significant in their contributions to the field and in their influence on women in the field.

I believe that their stories could be a major contribution to the science curriculum and that it could be a significant factor in encouraging girls to identify with the field.

In chapter two, I will examine the history of American women in science, from the pre-19th Century to the present, how this history has chosen to exclude most of the stories of women, and how this male domination has impacted our society's view of women in science. There have been significant changes that have taken place in the field to remove the barriers for women, yet women are still being discriminated against by receiving lower pay and being unable to break the barriers to achieve equal access to particular fields of science.

In chapter three, I will discuss critical theory and their work related to the relationship between knowledge and power, how power systems are used to create truth, and how the critical theorist work relates to those of science studies theorists who also question the power relationship in the creation of science knowledge. The major concepts of feminist science studies and their contribution to righting the historical record in science will also be discussed. This will provide a framework for my research.

In chapter four, I will discuss the male-centered influence in textbooks and how women's stories have been excluded from them. I will discuss the issue of who has contributed to the exclusion of these women in the science textbooks and how this exclusion has negatively impacted the interest of girls in science and their identification with the field.

In chapters five, six, and seven, I will present the stories of three women in the history of science: Rachel Carson, Ellen Richards, and Maria Mitchell, the struggles that they faced with gender discrimination in the field of science, and how they overcame many of

the formal and informal barriers to their inclusion in the field. The stories of these women are united in presenting how women have made significant contributions to the field of science. Their contributions are beyond simply their value as a female scientist; they individually contributed to changing the future of science. Each of these individuals had significant influence on future generations of women. These important stories show the power of role models and its ability to influence future generations.

I will discuss possible future influences that these stories could have on girl's identity formation and how significant an impact this can have at the middle school level. I will also explore the possible influence these stories could have to all students. Additionally, I will examine how a change of mindset could occur as a result of all students being exposed to women's contributions to the field in a meaningful way beyond the sidebar contributions. In examining the stories of these women, I will reflect the significance of their exclusion and the subsequent impact on the miseducation of students.

In chapter eight, I will conclude with how these women's stories and others could be used in the school curriculum, the influence it could have on girls identifying with science, and on those who teach science and their approaches to encouraging girls to participate in science related school activities.

CHAPTER 2

SCIENCE IN AMERICA: EXCELLENCE AND EXCLUSION

The preponderance of the published history of science in America is male-dominated. A survey of historical texts covering the development of science in the United States portrays fields ruled by near mythical male figures. Searching for females involved in scientific research in the United States becomes the hunt for the proverbial needle in a haystack. According to Kass-Simon (1990):

> One can open any history of science and find the works of hundreds of men who may have helped to create the substance of their discipline. And just as one can find name after name of men in these books, it is almost impossible to find the names of any women. (xi)

A review of the history leads one to believe that men have a near exclusive hold on the fields of science. The history of science has portrayed the field as being almost exclusively male.

> James McKeen Cattell, a professor at Columbia University and editor of *Science,* the official journal of the American Association for the Advancement of Science, noted that among his list of one thousand persons of eminence throughout the ages, only thirty-two were women (Fausto-Sterling, 2002, p. 267).

One must make a close examination of the history of science in the United States to locate women who have been identified as agents of change.

The search for female scientists in text is made troublesome for two reasons. The first is the exclusion of females from professional science in America. While females were

allowed to participate in a meaningful way in scientific investigations in the early stages of America's expansion, the majority of scientific fields became dominated by males as the country became a developed nation.

> Attempts to integrate women fully into the traditional heroic narrative are untimely, unlikely to be satisfying, not because women have ever been genetically inferior to men in intellect not because of social barriers that have historically denied women education and entrée into scientific professions. (Connor, 2005, p. 4)

The number of women who could gain entry into the narrative of science is extremely limited due to barriers placed in the way. The absolute quantity of scientific discoveries attributable to females that can be considered notable is significantly less than those of males.

While women have been excluded from participation in hard science fields in the United States, the problem is compounded by a biased construction of the history of science textbooks. This constitutes the second method of exclusion from the historical record of science in America. According to Kohlstedt (1999):

> Women have always investigated the world, exploring, analyzing, and using what they discover about the living and nonliving elements around them. They have shared their knowledge and have inevitably been part of the enterprise that became Western science, however obscure their participation has become in the historical record. (p. 1)

The stories of these women have rarely become a part of historical text of science in America. They have been allowed to fade away, while the stories of male counterparts have been passed down to encourage and inform future generations.

Prior to the 19th Century, the scientific community in the colonies and the United States can best be described as embryonic. The vast majority of resources in the developing nation were devoted to meeting the basic needs of the people and the development of a basic infrastructure. During this time period, science was considered a luxury.

In the United States, formal research laboratories in the colleges, universities, and corporations were almost nonexistent before the nineteenth century. Scientific research in America, much like the nation, was decentralized. Scientific investigation was primarily a cottage industry. Due to this fact, women were able to be heavily involved in scientific exploration in America during the seventeenth, eighteenth, and the beginning of the nineteenth centuries. "Well into the nineteenth century most scientific activity took place in private homes. This meant that, although women were excluded from universities and academic societies, they did become involved in science" (Fara, 2004, p. 39).

During this time period, women labored beside male counterparts researching the ecological and physical compositions of the New World. Many of the women involved in these pursuits did not earn rightful credit for their part in the scientific breakthroughs and discoveries made during this time. In this period, women were expected to mask their special skills and talents. Taking responsibility for such work would have violated the social norms of the time and led to ridicule or shunning.

Formal training in the sciences was extremely limited in the United States prior to the 19th century. Students interested in studying the sciences were typically sent to an institution of higher learning in Europe. Due to the enormous expense involved, very few women had the opportunity to complete studies abroad. These advanced educational opportunities were typically only available to the male members of wealthy families.

While the facilities and educational opportunities were very limited during this period it could possibly be viewed as the golden age of women in science in the United States.

> While science itself was heretical, women played prominent and central roles in it. From the sixteenth until the nineteenth century, the pursuit of expertise in scientific knowledge was considered a heretical alternative to the pursuit of classical knowledge. During this period, proponents of anticlassical education actively encouraged women to pursue science, and many did. (Eisenhart & Finkel, 1998, p. 32)

Females took advantage of the opportunities to pursue science, but they were not given rightful credit in historical texts of science.

As the United States developed, its scientific community became more formalized. At the beginning of the 19th century, the Industrial Revolution was changing America. As Eli Whitney's cotton gin and Robert Fulton's steam engine demonstrated the profitability of science, scientific activities left the home and moved into university and private research facilities. The increasing monetary needs of the scientist could no longer be met in the simple home laboratory. The Industrial Revolution brought a scientific revolution in the United States. The massive changes were detrimental to current and future female scientists.

> The goal was very explicitly to raise up a new generation in the established group's image and to disseminate ideas about science on terms it defined. The institutionalization of science was taking its now-familiar shape; scientific activities by state and federal governments were being gradually transformed into permanent agencies, colleges presumed science courses should be in their catalogues, and specialists created their own sections of the AAAS, produced journals, and moved toward separate societies. (Kohlstedt, 1999, p. 189)

As the process occurred, women were pushed into the margins or out of the scientific community totally. Only in a limited number of fields did women continue to pursue scientific knowledge without having to work under a male superior. "Mathematics, biology, geology, and astronomy were relatively easy to practice for they required little in the way of facilities or expenditures" (Rayner-Canham & Rayner-Canham, 1998, p. 28)

The small number of females who continued to labor in laboratories and other research facilities did so in near obscurity and were forced to work alongside male counterparts in order to gain legitimacy.

> Women were not to travel a public road in pursuit of science. With their exclusion from university, women had few options but to pursue science privately. In the nineteenth century, the normal pattern for women in science was that of the private assistant, usually a wife, sometimes a sister or niece, who devoted her life to a man as a loyal assistant and indefatigable aide. (Kourany, 2002, p. 29)

Females were only allowed to labor in the lowest of roles in the laboratory. Research was to be directed by male counterparts. They were designated as assistants regardless of their qualifications and duties.

During this time period, it became common practice for females to have their work attributed to others.

> Since very few women had access to formal education many women scientists were dependent on their fathers, brothers, or husbands for their training. This meant that they were in constant danger of having their work attributed to their male colleagues. (Alic, 1986, p.10)

The male seized hold of the intellectual breakthroughs produced by female colleagues. The women toiling away in the laboratory faded away in the mists of time.

"By the 1840s scientific activity gained visibility in more formal settings, and its advocates presented new and largely unprecedented claims for 'pure science'" (Kohlstedt, 1999, p. 189). As these scientific activities gained prominence and the practitioners of science grew in prestige, women were claimed to be incapable of performing pure science (Rossiter, 1994; Kohlstedt, 1999; Pattatucci, 1998).

As money into the sciences increased, women were declared to be incapable of administering the large projects that began to form. As science began the process of turning into big business, positions of importance were awarded to males.

The tumultuous years of the 1860s witnessed scientific activities in the United States nearly end. The nation was divided by the civil war. Money that had been previously allocated to scientific research were consumed by the expense of the war. The only projects to receive any significant quantity of funding were those that showed military importance.

In 1873, Dr. Edward Clarke published *Sex in Education, or a Fair Chance for Girls.* In this book he claimed that it was detrimental to women's health to attend college

(Hubbard, Henifin, & Fried, 1982). This work influenced many educational biases on women and higher education. It was profound in dispensing an abundance of myths about women's ability to perform educationally and used gender as a biological predetermination for intellectual functioning.

Many women during this time were attempting to dispel gender myths and encourage women to band together in the pursuit of their inclusion in science. In 1873, Jane C. Croly and Maria Mitchell officially founded the Association for the Advancement of Women. The association provided the first network for women including female science faculty from across the nation. Additionally, Croly and Mitchell used the association as a forum to speak for the equality of women.

Mitchell, as part of her work as president of the association, annually compiled a report on the state of female employment in the sciences at institutions of higher learning and in the public sector. The report marked the first time a large-scale study of female involvement in the sciences had been undertaken.

The closing of the nineteenth century witnessed the first major expressions of the women's rights movement in the United States. The words of Susan B. Anthony (1899) capture the sentiment of the movements.

> Who can measure the advantages that would result if the magnificent abilities of these women could be devoted to the needs of government, society and home, instead of being consumed in the struggle to obtain their birthright of individual freedom? Until this be gained we can never know, we cannot even prophesy the capacity and power of women for the uplifting of humanity. (Anthony in Biggs, 1996, p. 186)

The early years of the 19th century marked a turning point in the education of women in the United States. Before this time period, formal, public education for women was "practically nonexistent" (Warner, 1999, p. 191). It was feared that a formal education would radicalize a woman. Women interested in the sciences had to seek out informal modes of learning such as public lectures, museums, and trade books (Rossiter, 1984; Warner 1999). A large segment of American society considered an educated woman a threat to the fabric of the nation (Rossiter, 1982). In 1815, the Louisburg Female Academy became the first institution of higher education for women in America. On the heels of Louisburg, private women's seminaries and academies began to be established across the country. While these institutions lacked the resources of their male counterparts, the seminaries and academies provided access to a higher level of education than were offered to women before (Warner, 1999; Rossiter, 1984). While many of these institutions offered survey courses in biology, botany, and astronomy, the classes provided only a brief introduction to a variety of topics and did not prepare the students for a career in the hard sciences. The main purpose of these institutions was the preparation of females to become effective mothers. It did not deem them in need of science knowledge beyond the rudimentary level.

The mid-19th century witnessed an explosion of colleges for women and the admittance of women to private and public coeducational institutions of higher education. The Civil War had a major impact on the educational possibilities of women. Before the start of the war, only three private and two public universities were coeducational institutions. Since the number of males seeking higher education decreased significantly

during the Civil War, the number of colleges and universities allowing women to enroll increased dramatically (Harwarth, Maline, & DeBra, 2001, p. 4).

While the number of women scientists produced by these institutions was small, the colleges provided opportunities for women to become faculty members. By the close of the century, women held over 400 faculty positions at institutions of higher education. Most of these positions were held at women's colleges.

The female science faculty of these institutions provided educational opportunities for more than just the students who attended these colleges. Texts produced by the faculty became popular with females in the general population. *Conversations in Chemistry* by Jane Marcet and *Familiar Lectures on Botany* by Almira Hart Lincoln Phelps sold over one hundred thousand copies each. These texts provided practical information in the sciences that could be understood by the average layperson. The books helped spark an increased interest in the sciences especially among females.

The 20th century marked a period of significant change in the United States.

> By 1920 the women scientists had gone through a rapid series of social and political movements. Feminism had led some of them to challenge old beliefs about women's inferiority, the suffrage movement had called forth active campaigns in many states and the nation's capital, and the war had utilized some of their skills and talents. (Rossiter, 1984, p.122)

The women's suffrage movement and the First World War began to significantly change the structure of the scientific community. Proponents of a woman's right to vote argued against the belief in the mental inferiority of the female sex. The work of these women

challenged the common belief in the male's intellectual superiority. It was during this time that the previous work of women suffrage pioneers began to gain popularity.

When the United States became embroiled in World War I it depleted the male population and led to females filling both university and private sector positions. While the gates were not opened enough to allow females to flow freely into positions in science fields, a significant number did gain entrance to some degree.

In the 1930's anthropologist Margaret Mead published results of her studies of people in New Guinea. Her books, *Coming of Age in Samoa* and *Sex and Temperment in Three Primitive Societies* were significant in raising public awareness of gender roles being culturally influenced not genetically predetermined personality traits. Her observations of how men's roles and women's roles were reversed in the Tchambuli culture led her to challenge the popular viewpoint of hereditary gender roles. She found that culture was a more prominent influence on personality and gender roles. This had a major impact in changing the viewpoint that women's roles were genetically determined.

In the 1940s there was a significant increase of females into science and engineering positions in the United States, but they were "considered temporary employees. 'keeping the seat warm' for men assigned to other, higher-priority wartime duties" (Rossiter, 1995, xv). As the male population were sent to war, women were called upon once again to fill roles. Even in this time of desperate need, females failed to enter the upper ranks of the scientific community in significant numbers. Most of the females were issued employment as laboratory aids and assistants.

Though their numbers were limited, a select few female scientists did gain recognition and rise to positions of power during this tumultuous period. Some women directly

involved in the war effort found success. Leona Woods Marshall Libby, Maria Goeppert Mayer, and Lilli Schwenk Hornig contributed significantly to the chemical and nuclear physics breakthroughs that helped to provide the United States with military advantage over the remainder of the world. Each of these women worked on a segment of what would come to be called the Manhattan Project. Mary Sears, Florence van Straten, Grace Murray Hopper, and Mina Rees served in the United States Navy during the conflict and made contributions to the fields of oceanography, meteorology, and engineering (Williams, 2001).

Unfortunately, only these select few women were able to achieve substantial success and receive appropriate credit. Even though women contributed substantially to the safety of the nation, they still were not treated on par with their male colleagues.

> Though thousands of women, as Navy WAVES or Army WAACs, were engaged in scientific work for the military during the war few were in positions that allowed them to do high level scientific work and even fewer were allowed to attain the military rank accorded them by that work. (Shell-Gellasch, 2002, p. 52)

While women were allowed to provide the necessary knowledge and skills that advanced the war effort, they were not allowed to advance themselves due to gender bias. While male scientists advanced quickly through the ranks and were given increasingly larger budgets and research personnel, females languished in positions far beneath their abilities.

In 1945, as the war ended, droves of men returned to the colleges, universities, and private sector and replaced the women keeping their seats warm. Women heavily involved in scientific breakthroughs that aided the war effort failed to achieve positions

equal to their male colleagues. Many of these women labored in the laboratories of men whose accomplishments paled in comparison to their own.

The year 1947 was significant due to the first American female scientist, Gerty Cori, earning a Nobel Prize in science. She was credited with developing the foundation for understanding how cells convert food into energy. "The Cori cycle has become such a basic part of high school science that it is easy to forget how revolutionary it was during the 1920s. For the first time, it was possible to show how muscles use sugar for quick energy and how the muscles and liver store excess energy until it is needed" (McGrayne, 1998, p.93). Her work influenced many other scientists including eight alumni of the Cori lab who won Nobel Prizes.

The 1950s and early 1960s saw limited growth in opportunities for females in science and engineering. Females still failed to secure employment as governmental advisors, become officials in scientific societies, and win major prizes (Rossiter, 1995; Wear, 1997; Eisenhart & Finkel, 1998).

Even the increased demand for scientists, engineers, and mathematicians caused by Kennedy's race into space during the 1960s did not significantly expand opportunities afforded to women. Kennedy proudly announced that the United States would send the first man to the moon through a concerted effort by the greatest minds our nation had to offer. The greatest minds were overwhelmingly deemed to be male. Only limited access to federal positions to work on the massive project were given to women. Increased employment opportunities in technology, spawned by the race to the moon, were reserved primarily for males. The increase of interest in the advancement of science and technology was to defeat the competitor, Union of Soviet Socialist Republics, in the

space race. This movement however, did not bring about a significant increase in public and private sector science opportunities for females.

Despite the overall state of females in the sciences not showing improvement a small number of females made achievements that were so significant they could not be ignored. The groundbreaking work of Barbara McClintock could not escape notice. Her findings led to a new understanding of the workings of chromosomes and are fundamental to our understanding of genetics today.

In 1962, a pioneer of environmental science awareness, Rachel Carson, published her groundbreaking work *Silent Spring*. Her book exposed the dangers of pesticides to the public. Her influence on public awareness led to the banning of DDT in the United States and the creation of the Environmental Protection Agency (EPA).

In the 1960s, the civil rights movements began to open doors not only for racial minorities but also for women. Women began to organize and rally for change in the exclusionary policies that barred their full participation in colleges, universities, government, and the private sector. The battles fought for equality did not result in immediate gains in the form of increased female participation in the sciences and engineering. The battle against formal barriers to entry into preparation programs in science, engineering, and mathematics would carry on into the next decade.

In the 1970s, The Equal Rights Amendment failed to be ratified by a majority of the states. The women's movement did not gain a formal recognition but the passage of other significant legislation did increase the opportunities of women. The most significant piece of legislation that increased women's educational opportunities was the Educational Amendments of 1972 and specifically Title IX of the amendments. "Before Title IX, high

schools typically sex segregated classes: girls took home economics, boys took shop; while boys were encouraged to take math and science courses, girls were dissuaded or even prevented from enrolling in these courses" (Zitterman & Sadker, 2003, p. p. 3). In the years since the passage of the Title IX, the number of women enrolled in science courses at the high school level has increased significantly. In several high school courses, the number of women enrolled has surpassed the number of men.

While the policies and procedures that denied women entry into programs in the sciences were officially abandoned by institutions of higher education, the social forces at work were not as easily reformed.

> Women in science were not acclaimed for their achievements but rather were singled out for their oddities, were resented by other women, especially subordinates, and were considered socially inadequate if they were unmarried. It would take changes in behavior as well as laws for women to be fully accepted as scientists. As it was, they had to have a "hardy spirit" to stand up to the many obstacles they faced. (Rossiter, 1995, p. 368)

The social obstacles which have persisted since the passage of Title IX have continued to support the under representation of females in the hard science fields. Women in the chemistry, physics, or engineering lab are still viewed as an anomaly. When a female advances in one of these fields of endeavor, her successes are frequently credited to affirmative action policies and not merit.

In 1983 Sally Ride became the first American woman astronaut to travel into space. Twenty-two years earlier, Alan Shepard was the first man in space. The year 1983 marked the beginning of women astronauts.

In March of 2007, the Committee on Science, Engineering, and Public Policy of the National Academies, chaired by Donna Shalala, released its comprehensive study on the state of women in science, *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering.* This study examined the gender disparities found in private and public employment in science and engineering fields.

> In counterpoint to that dramatic educational progress, women, who constitute about half of the total workforce in the United States and half of the degree recipients in a number of scientific fields, still make up only one-fifth of the nation's scientific and technical workers. At every academic career milestone the proportion of women in science and engineering declines. These declines are evident even in 2003, the most recent year for which data are available. (p. 13)

While Title IX has increased female participation in science preparation programs, the proportion of women in science and engineering have not increased significantly. The continuation of the power structures in place despite the mandates of Title IX has acted to distract women from actively pursuing careers in science.

> The discrimination results from a combination of built-in biases that make them less likely to hire a woman than a man with identical accomplishments, of evaluation criteria that contain arbitrary and subjective components that disadvantage women. For instance, characteristics that are often selected for and believed to relate to scientific creativity — namely assertiveness and single-mindedness — are both given greater weight in hiring and promotion than traits such as flexibility, diplomacy and curiosity, and stereotyped as socially unacceptable traits for women. (Lederman, 2006, p.1)

Since the founding of the United States, women have been significantly underrepresented in the fields of science and engineering. While the numbers have increased as the years have flowed by, equality has not been reached. According to Kantrowitz and Scelfo (2006):

> To women in other professions--law, publishing, even politics--science can sometimes seem like the world that time forgot. Decades after women began scaling the corporate ladder, female physicists, chemists, mathematicians and engineers are still struggling to find their place at the nation's major research universities. (p.1)

The professions in the field of science have been so influenced by a gendering of the field that it has fallen behind in its inclusion of women. While many other fields have been able to overcome stereotypical cultural assumptions, science continues to show significant male influence and diminished female representation.

There are significant barriers to women who achieve status as a scientist. The barriers to obtaining a high-ranking position in science are not the only obstacle. “Women in science still routinely receive less research support than their male colleagues, and they have not reached the top academic ranks in numbers anything like their growing presence would suggest” (Dean, 2006, p. 1). The history of American women in the sciences has shown a significant increase in women’s involvement in the field. However, they have not reached the top academic ranks as their increase in numbers would expect. Women scientists are still struggling the battles of their predecessors and fighting for equality with men in the field of science.

CHAPTER 3

THE DISCOURSE OF CURRICULUM: KNOWLEDGE AND POWER

According to Pinar (2004), "Despite the heroic efforts of millions of teachers, the schools have been-are today-complicit in the miseducation of the American public" (p.16). The American educational system is primarily organized to produce the next generation of workers and not individuals capable of independent thought. A litany of scholars such as Michael Apple, Henri Giroux, and bell hooks have cast a critical eye on the process of schooling in the United States. Giroux (1999) states that the purpose of a critical examination of the educational process is to ensure that school processes can be "informed by a public philosophy that addresses how to construct ideological and institutional conditions in which the lived experience of empowerment for the vast majority of students becomes the defining feature of schooling" (p. 1).

Most important in the examination of schooling to the critical theorist is the control of knowledge. The control of the flow of knowledge equals power. In *Educating the "Right" Way,* Michael Apple (2001) finds:

> If we have learned anything from the intense and continuing conflicts over what and whose knowledge should be declared "official" that have raged throughout the history of curriculum in so many nations, it should have been one lesson. There is an intricate set of connections between knowledge and power (p. 6).

Knowledge and power are closely interwoven. Whether the knowledge gives one the capability to manipulate political systems or complex technology, it imbues the knower with power (Freire, 1970; Shor & Freire, 1987; Giroux, 1999).

The official knowledge proclaimed by the system becomes truth. These truths proceed largely unchallenged and lead to acceptance of the status quo.

> Knowledge is often accepted as truth legitimizing a specific view of the world that is either questionable or patently false. The selection, organization, and distribution of knowledge is hidden from the realm of ideology. In addition to its overt and covert messages, the way knowledge is selected and organized represents *a priori* assumptions by the educator about its value and legitimacy. (Giroux, 1999, p.9)

Knowledge is organized by those in power to legitimize the current structure of the world. The way knowledge is selected leads to an understanding of its importance.

The works of critical theorists argue that multiple perspectives expand our knowledge of the world. According to Maxine Greene (1995):

> To open up our experience (and yes, our curricula) to existential possibilities of multiple kinds is to extend and deepen what each of us thinks of when he or she speaks of a community. If we break through and disrupt our surface equilibrium and uniformity, it does not mean that a particular ethnic or racial tradition will, or ought, to replace our own. (p. 161)

The acceptance of multiple perspectives is not to diminish but to expand. By increasing the number of voices heard, the community extends, deepens, and strengthens. It is through multiple perspectives that knowledge is acquired.

Science studies examines science and the game of knowledge creation developed within the system. Beginning with the groundbreaking work of Thomas Kuhn, science studies has emerged as a critical examination of the science. Kuhn's work is considered

one of the most significant in the field of science history due to his introduction of the theory of paradigm shifts. His concept is fundamental in understanding the development of science.

> Men whose research is based on shared paradigms are committed to the same rules and standards for scientific practice. That commitment and the apparent consensus it produces are prerequisites for normal science, ie., for the genesis and continuation of a particular research tradition. (Kuhn, 1996, p. 11)

Kuhn's examination of science driven by paradigms explained how science knowledge becomes accepted and how it can change over time. Science knowledge is a process that travels through revolutions (or beliefs) as paradigms shift. Kuhn's work was important in explaining how science creates knowledge and that over time it is not definitive knowledge but that which is most accepted at any given time.

Most of the work of science studies scholars are based on Kuhn's groundbreaking work *The Structure of Scientific Revolutions.* His examination of the social and historical development of the field of science and the role of power in knowledge development led to many fields outside of science beginning to examine it.

For the majority of humankind, the scientist is believed to be the seeker of Truth. The scientist is only constrained by the limits of the current technology. Unfortunately, the scientist faces not merely restraints caused by equipment available but also social, political, and philosophical constraints. According to Kuhn (1970):

> Under normal conditions the research scientist is not an innovator but a solver of puzzles, and the puzzles upon which he concentrates are just those which he

> believes can be both stated and solved within the existing scientific tradition (Kuhn, 1970, p. 52).

This view of the scientist as solver of puzzles questions the belief of the authority of the scientist. The privileged viewpoint of the unbiased scientist is replaced with one of an individual limited by their own scientific traditions.

Lyotard discusses science as a game of players that use language games in the development of their status as true knowledge.

> It is useful to make the following three observations about language games. The first is that their rules do not carry within themselves their own legitimation, but are the object of a contract, explicit or not, between players (which is not to say that the players invent the rules). The second is that if there are no rules, there is no game, that even an infinitesimal modification of one rule alters the nature of the game, that a "move" or utterance that does not satisfy the rules does not belong to the game they define. The third remark is suggested by what has just been said: every utterance should be thought of as a "move" in a game. (Lyotard, 2002, p. 10).

Science is a game that uses language games to practice science. It is within these rules of language games that scientist perform the self legitimation and Truths.

Science studies examines the viewpoint that the scientist is but one type of observer of the world. "Nothing is ever settled, no viewpoint can ever be omitted from a comprehensive account" (Feyerabend, 1993, p.21). This belief in nothing in science being settled challenges the belief in the definitive science laws and brings into question the universe as a game of chance.

> But according to the quantum laws, even if you make the most perfect measurements possible of how things are today, the best you can ever hope to do is predict the probability that things will be one way or another at some chosen time in the future, or that things were only one way or another at some chosen time in the past. The universe, according to quantum mechanics, is not etched into the present; the universe, according to quantum mechanics, participates in a game of chance. (Greene, 2004, p.11)

If the universe participates in a game of chance, the scientist cannot proclaim any viewpoint out of the realm of possibility. Science studies examines science as a creator of reality.

> Instead of a mythical Mind giving shape to reality, carving it, cutting it, ordering it, it was now the prejudices, categories, and paradigms of a group of people living together that determined the representations of everyone of those people. (Latour, 1999, p. 6).

The prejudices, categories and paradigms of a group of scientists are representing those of everyone else. It is the exclusion of other viewpoints that makes science susceptible to bias.

The work of science studies scholars began to question the authority of the scientist. In questioning the production of knowledge, the scientist became less glorified. Science studies proclaimed that "…science knows no 'bare facts' at all but the 'facts' that enter our knowledge are already viewed in a certain way and are, therefore, essentially ideational"(Feyerabend, 2002, p. 11). By examining science as lacking bare facts one can begin to question the authority of the scientist proclaiming to have proof. It is the

questioning of the authority of the scientist that feminist science studies scholars rely on to examine the exclusion of women in the creation of the paradigms of science. This paved the way for other areas of study. One of those is the field of feminist science studies. This field took shape in the same questioning of the scientist with its focus on the exclusion of women in the field. According to the Association of American Colleges and Universities (1999):

> Feminist science studies has brought to the study of science an awareness of the costs of excluding women and the other marginalized groups from full participation in science. Part of the loss is to those excluded individuals who, because of their sex, racial-ethnic background, or class, have been deprived of the pleasures and challenges, the rewards and power, or studying and doing science. But society as a whole has lost out on the talents and insights that they could have brought to science and technology. (p. 4)

The past 50 years have seen a significant change in attitudes toward women in science, however, there are still significant problems with the gendering of the field of science and in its subsequent treatment of women. History has not reflected the importance of women and their contributions to the field of science. Every field of science has numerous examples of women who were not given recognition in popular science for their work. Many of these women's stories have been marginalized and have only been kept alive by feminist writers. The history of science has been cruel to the memory of many women who contributed to the field in monumental ways. Feminist science scholars are attempting to rectify these oversights.

> Historical studies and biographies of contemporary scientists bring to our attention the "women worthies" in science: the many women who have made important contributions but who are ignored or devalued in the androcentric mainstream literature. A new generation of historians is bringing to bear on the lives of these women the insights of several decades of feminist approaches to women's history (Harding, 1991, p. 22).

This new generation of historians are finally shedding light on the corners of science history where women have been pushed. In Margaret Alic's book, *Hypathia's Heritage: A History of Women in Science from Antiquity to the Late Nineteenth Century,* she traces the history of the lost heritage of women in science and exposes the myth that women have not been involved extensively in science until modern times.

> But women are fighting back. They are speaking out against such patriarchal attitudes. They are asserting that women, including women scientists, can change the world. And one step toward such change is to rediscover the history of women in science (Alic, 1986, p. 3).

Her work is one of many examples of women historians seeking to bring the history of women in science to mainstream knowledge. Margaret W. Rossiter's contribution to include the stories of women in the historical record of science includes her books, *Women Scientists in America: Struggles to 1940* and *Women Scientists in America: Before Affirmative Action, 1940-1972.* In these books she cites numerous examples of women who influenced the growth of American science and challenges the belief that men have contributed all of the significant scientific achievements in history.

Feminist science studies scholarship has developed from the core belief that women are as capable of performing in science as men. “Since the time of Poullain de la Barre, liberal feminists have tried to fight science with science, claiming that because anatomists have found no significant difference between men’s and women’s brains or sense organs, women are as capable as men of contributing to science” (Schiebinger, 1989, p. 274). Feminist science studies scholars attempt to expose the fallacies that proclaim women to be inferior to men in science. Many of these scholars are women scientists in the field who believe women have been historically denied full equality in the fields of science and that their participation has been limited by those in powerful positions. Feminist science studies examines how science has excluded women based on the dominant influence of men in the field.

The term feminist science studies is a modern term for a much earlier idea. Historically, there have been many women who have fought for equality in science. The feminist science movement is based on the tenets of those earlier women. They are concerned with the way women are being marginalized by the field of science. From their exclusion from historical record to the current belief that women are innately inferior to men in their ability to perform in science, these scholars seek to abolish these misconceptions by questioning the science historical record.

In order to view science from a different perspective, feminist science studies scholars believe that the history of science must be reexamined. The exclusion of non-Western, non-white males has not given its history an accurate portrayal.

> In particular, the lesson I intend to impart is that the dominance of white male Westerners in science impoverishes science on its own terms, and that the

> inclusion of excluded others will improve the content and the very objectivity of science (Cudd, 2000, p. 299).

Science needs to examine its history from the perspective of the lesser known in history. The facade of only male figures as being the 'fathers' of science needs to be revised to include the tale of the 'mothers' who were not given recognition for their work. Most of the stories of these women were not included in popular science books. Feminist science scholars plea for readers to seek beyond the mainstream literature for a more broad perspective of history.

> Historical studies and biographies of contemporary scientists bring to our attention the "women worthiness" in science: the many women who have made important contributions but who are ignored or devalued in the androcentric mainstream literature. A new generation of historians is bringing to bear on the lives of these women the insights of several decades of feminist approaches to women's history (Harding, 1991, p. 22).

This new generation of historians is attempting to right the record and ask why have so few women been included in the history of science? The historical record of women in science has been significantly altered to exclude women from recognition.

> One can open any history of science and find the work of hundreds of men who may have helped to create the substance of their discipline. And just as one can find name after name of men in these books, it is almost impossible to find the names of any women. In Asimov's popular *Biographical Encyclopedia of Science and Technology* only 10 women are listed among the 1,195 scientists whose work is described (Kass-Simon, 1993, p.xi).

Feminist science studies scholars believe that the history of science should be corrected to include the many important women figures and their contributions to science. They are concerned with those who were forgotten, and those who were misrepresented. Feminist science scholars question why the history of science has excluded these women and how their exclusion may have impacted its conceptual viewpoints. By examining the lives of female scientists of the past, these scholars aim to right the historical record and change public perception of women's ability to perform science.

Despite common belief, women have been contributing to the field of science for thousands of years. "But surprisingly, given what our science textbooks and histories of science have prepared us to believe, women have always been scientists as well. Indeed, we have historical evidence of women's scientific activities dating back six thousand years" (Kourany, 2002, p.3). In China, 2640 BCE, Si Ling-Chi invented the process called sericulture-the science of silk production. "She learned to cultivate silkworms, to reel the fibers, to test for strength and reliability, and how to weave it into garments" (Northeast Public Radio, 2005, p. 1). She is still worshiped in China as the "Goddess of Silk". Alchemist Maria the Jewess (1st Cent. BCE) engineered distillation instruments including the double boiler. Hypatia (370-415 C. E.) was a scientific scholar who influenced the field of science for hundreds of years. She was instrumental in the development of the astrolab, hydroscope, and planisphere; twelve to fourteen hundred years after her death Decartes and Newton based their work on her theories (Northeast Public Radio, 2005).

Women have always been engaged in scientific endeavors despite what the historical record reflects. These women's contributions were forgotten or never included in

mainstream science so it appeared that they did not participate. “Women’s contributions to the history and practice of science are not limited to the achievements of a few extraordinary individuals. The new women’s history and sociology have directed attention to the less public, less official, less visible, and less dramatic aspects of science in order to gain a better understanding of women’s participation in these enterprises” (Harding, 1991, p. 25-26). Unfortunately, creative and talented female scientists and inventors were largely ignored. Largely characterized as only amateur scientist’s or social rejects by their male contemporaries, their genius was never recorded in the annals of mankind.

Refusing to follow the dictates of the time, these brave women ventured into what was considered the realm of men. Women scientists in the past were challenging their society’s beliefs by performing these scientific activities. They were challenging the false belief that women were not capable of being scientists. The field of feminist science studies is a modern term for those who are continuing the struggle for women’s equality in science. These scholars share a common belief that women have been and continue to be excluded from the historical record in science based on gender discrimination. They examine gender relations and its influence on the field of science.

It is the belief of most scientists that there is one universal truth about the world and that their expertise makes them capable of determining it above other belief systems. However, science is a belief system among many others. It creates its own rules and proclaims its findings valid. “…[T]he man who reads science text can easily take the applications to be the evidence for the theory, the reasons why it ought to believed. But science students accept theories on the authority of teacher and text, not because of

evidence" (Kuhn, 1996, p. 80). It is the acceptance of the authority of teacher and text that leads to the belief in paradigms. Feminist science studies seek to examine how gender has influenced the acceptance of science paradigms. The patriarchic history of science has excluded women from participating in many of the paradigms of science.

> Building on the groundbreaking work of Thomas Kuhn, feminist science studies scholars have argued that scientific objectivity doesn't simply rest with individual scientists. Instead, it is the result of a consensus reached by a community of scientists working within a cultural context. The fact that communities of scientists have traditionally been comprised primarily of white men of privilege has had a profound impact on how scientific practice and understandings of objectivity have developed. (American Association of Colleges and Universities, 1999, p. 8)

Feminist science studies scholars challenge the belief in the traditional white men of privilege scientists who proclaim their preferential position in the field. They understand that a consensus reached among a community of scientists of different cultural backgrounds would be a more objective viewpoint. In the past, medical research has significantly overlooked women's health issues until women were allowed to participate more substantially in the field. "Only when women were able to increase their presence among the ranks of working health researchers, physicians, and health policy decision makers did they begin to make an impact on changing medical priorities, and most would agree that recent progress is only the beginning" (Morse, 1995, pp. 29-30). It is the inclusion of the viewpoint of women that is having an impact on the medical field. The lack of significant female influences in the field lead to it being too narrowly focused on

male issues. It is important that science remain accessible to all for it to maintain objectivity. Feminist standpoint theory examines this issue. It acknowledges that an individual's standpoint in society affects their viewpoint and subsequent approaches to understanding the world.

> One of the goals of standpoint theorists is to describe the social and political hierarchies of modern science, which might include looking at gender and racial makeup of scientists, class issues, issues of ethnicity or nationality, sexual preference, or others as they relate to science culture. From these questions follow questions about the relationship of science, historically dominated by white males, to those who have until recently simply experienced its effects, namely women, nonwhites, non-Western people, and nonscientists (Morse, 1995, p. 25).

It is only with the inclusion of multicultural viewpoints that science can seek to be objective. It is the belief of standpoint theorists that there are standpoints that are based on a person's position in society and that those viewpoints should not be ignored. Some feminists believe that there are gendered viewpoints about nature and that the exclusion of that viewpoint has led to a misrepresentation of our world. "Many readers will find it strange and objectionable to consider the possibility that there are such things at all as gendered standpoints on nature-women's and men's distinctive relationships to the natural order"(Harding, 1998, p. 90). Standpoint theorists believe that there are differences in viewpoints about science between women and men based on their social situations. What research an individual may choose to participate in could be correlated with what is most relevant to their lives.

Most feminist theorists distinguish between sex and gender. Sex is the biological difference between males and females, while gender is the role society places on those sex differences. It is the social expectations that are associated with gender that play an important role in the appearance of differences in the sexes. Masculine and feminine traits are gendered. Since males have been more influential in the gendering of the field of science, it has become associated with masculine traits. Instead of science including both feminine and masculine roles, science has become associated with male traits. From this foundation, it has been proclaimed that men are naturally inclined to science. This false belief has contributed to the structural obstacles that women face in the field. "One must emphasize that structural obstacles should be the focus here-not the purported biological or personality traits on which the sexist attempts to explain women's lack of equity in science have concentrated" (Harding, 1991, p.29). The belief that men are innately more capable in science is false. The claim that women are innately less capable of science due to personality traits is a fallacy. The association of science with particular traits is socially constructed. There is no science personality or innate science traits. Science is what society has created it to be. Proclaiming women to be innately less capable of scientific thought is gender biased. It is used to justify the domination of men and the exclusion of women in science.

> The identification between scientific thought and masculinity is so deeply embedded in the culture at large that children have little difficulty internalizing it. They grow up not only expecting scientists to be men but also perceiving scientists as more 'masculine' than other male professionals-for example, those in the arts (Keller, 1985, p. 77).

The identification of scientific thought as being innately male has been ingrained into our culture. It is the strong influence of males on the field that has perpetuated this belief.

The influence of men on the field of science has developed it into its current state. It is that influence that has contributed to the viewpoint that science was founded exclusively by the patriarchal fathers of science. It was from the vantage point of those men that the history of science has developed. "Science is a human activity inseparable from the societal atmosphere of its time and place. Scientists, therefore, are influenced-consciously or unconsciously- by the political needs and urgencies of their society"(Fausto-Sterling, 1985, p. 208). The societal atmosphere and its subsequent influence on women being viewed as inferior to men has influenced how they are viewed in science. Feminist science studies seek to understand the mechanisms that have created this inequality for women in science and how their viewpoints have been devalued. Scientists who influence what is deemed as truths are predominantly prestigious white males.

Feminist science studies seek to expand science to include more than the perspective of the dominant class. In doing this, they do not seek to devalue the previous accomplishments of those scientists. They acknowledge the importance of their contribution, however they disagree with the exclusion of other viewpoints that may conflict with their work. They are working to ungender the field of science. The importance of seeing from a different viewpoint is an important aspect of the feminist philosophy, "feminism teaches women (and men) how to see the social order from the perspective of an outsider" (Harding in Lederman/Bartsch, 2001, p.148). Looking at social order and its influence on knowledge is how one can see from another perspective. In understanding this one can understand how knowledge is socially situated.

The socially situated knowledge that women are innately less capable of scientific endeavors has led to fewer women being scientists. Feminist science scholars have asked why so many women are not interested in science. The common belief was that women needed to be encouraged to want to learn about science. The years of reforming science education has led to significant improvements in the number of women in science but it has not lived up to the equality that was anticipated. It was more than mere inclusion in the field and exposure that was deterring women from science. Societal expectations and pressures have helped to perpetuate the stereotyped roles. Girls are taught at an early age the way they are expected to act. These feminine expectations are often incompatible with the masculine portrayal of science. Many girls are reluctant to pursue the field because they perceive it to be for boys. This misconception is perpetuated by the lack of female role models studied in the history of science, societal expectations of what is feminine, and by the belief in the innate male ability to perform in science.

Many of the feminist scholars are not satisfied with the mere inclusion of women in the field. Sandra Harding asks, "should women want to become "just like men" in science, as many of these studies assume? That is, should feminism set such a low goal as mere equality with men?" (1986, p.21). She asks if women should aim to be "just like men" or if the field of science itself should open to a feminist viewpoint. Many women in the field have reported that they have had to assume the male perspective in order to be accepted in the field. If a woman is to be in the field it is assumed that she will act like man. This inclusion of women in the field is simply that they are physically included but not that their viewpoints are accepted. The common beliefs that have shaped science have been dominated by a male perspective. It is this perspective that has made it difficult for

women to be accepted as real scientists not as an assistant to a male scientist. "[F]eminism teaches women (and men) to see male supremacy and the dominant forms of gender expectations and social relations as the bizarre beliefs and practices of a social order that is the "other' to us (Harding, 2001, p.148). Feminism challenges the beliefs and practices of science and exposes the social construction of their inception.

The belief that everything important in science has been accomplished by men has been perpetuated by male historians. The repression of women in the field has ranged from being physically excluded from participation to the falsification of their accomplishments in the historical record. Women were often viewed as assistants or otherwise labeled to justify their exclusion. Feminists seek to expose these shams and publicly acknowledge the accomplishments of those forgotten women. The history of science is filled with stories of women who were not given fair credit for their contribution to science. While skeptics may debate the validity of some of these women's stories, it is apparent by the numerous omissions that women were not being treated on an equal scale with their male counterparts.

According to Kuhn (1996), "What a man sees depends both upon what he looks at and also what his previous visual-conceptual experience has taught him to see" (Kuhn, 1996, p.113). This belief in the influence of individual perception is what challenges the idea that scientific knowledge can be finite.

The game of science is one that uses manufactured knowledge to proclaim scientific proof. Feminist epistemology refers to this type of knowledge as situated knowledge. Donna Haraway discusses this idea of situated knowledge in her essay, *Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective.*

> …[S]cience- the real game in town-is rhetoric, a series of efforts to persuade relevant social actors that one's manufactured knowledge is a route to a desired form of very objective power. Such persuasions must take account of the structure of artifacts, as well as of language-mediated actors in the knowledge game (Haraway in Lederman & Bartsch, 2001, p. 170).

This claim of knowledge that science refers to as truth is influenced by the individual's personal interpretation based on their social situation. The understanding that one cannot be independent of their own situated knowledge is what interferes with the attainment of true knowledge. People experience the world with their own senses and previous knowledge. Each person's situation is unique, they are situated in their own frame of knowledge. This includes gender, race, ethnicity, and social standing. Furthermore, Haraway proposed that individuals in inferior positions are less likely to deny the influence of situation on knowledge.

> The standpoints of the subjugated are not 'innocent' positions. On the contrary, they are preferred because in principal they are least likely to allow denial of the critical and interpretive core of all knowledge. They are savvy to modes of denial through repression, forgetting, and disappearing acts- ways of being nowhere whiled claiming to see comprehensively. (Haraway in Lederman & Bartsch, 2001, p. 175).

Many feminist science scholars believe that an entire reform of science is needed in order for women and other minority viewpoints to be included. That merely accepting women into the field and allowing them to do science as men do it is not enough. They would like to see women having influence on science and its principles. Many of the

reformation efforts have been unsuccessful because women are limited within the field simply based on their gender.

Like the reconceptualist movement, feminist science studies seeks to change the field of education. To include those who have been excluded from the dominant viewpoint, and those who are marginalized for their minority status. Curriculum theorists seek to open the field of curriculum to evolve away from answers and toward the questions. By doing this they want to remove the belief in truth, to be replaced by truths. Scientific theories should not be accepted as truth. "That is the function of theory. It is not to find an eternal truth, to establish for now and evermore "what works", or what's right. Theory functions to provoke you to think" (Pinar et. al., 1996, p. 8). Theory should be deemed that which is not proven, thus a theory, not a truth. Science has become so absorbed in its self-legitimacy that it fails to see anything outside of it.

Understanding science from the perspective of women has exposed the many fallacies in the framework of its beliefs. The inclusion of differing viewpoints is important to make science less exclusive. Feminist curriculum theorists have analyzed the importance not only in the inclusion of women but also in a feminist viewpoint.

> [F]eminist curriculum theorists and others committed to gender analysis will no doubt continue to confront the ways all of us, especially students perhaps, are affected, often in brutal ways, by the gender system that forms and deforms us (Pinar, et.al, 1996, p.403).

It is this commitment to confront the ways the gender system has affected our knowledge that unites curriculum theorists and feminist science scholars. By exposing the system that created this inequality, one can begin to move beyond the metanarratives into the

open spaces of possibility. The idea that all knowledge is simply narrative knowledge is difficult for science to accept. The idea of scientific proof has become a household name. However, philosophers of science suggest that is simply a metanarrative.

Feminist science studies scholars are committed to righting the record of women in history. By writing about the travesties of the past, they seek to amend flaws in the historical record and attribute honor to those who contributed to the field without deserved recognition.

Feminist science studies seek to update the historical record to include women who were not given credit for their contributions to science. They challenged the historical record and exposed the cultural and social influences that created the mistaken record. In exposing these social forces, they also challenge the misuse of science that is often used to proclaim men to be superior to women. Differences in men and women are examined by looking at social and environmental influences. "There is growing evidence that differences in physical strength could come from differences in life experience as from innate factors" (Lowe in Hubbard, Henifin, Fried, 1982, p.93). The differences in physical strength that are often used to justify women's inability to perform on certain jobs could be from the life experiences that have hindered her development in necessary strength. The same could be true for intellectual performance.

Feminist science studies also examines the role that gendering of the field of science as masculine has had on the involvement of women in the field. How the field structurally excludes women by its fundamental beliefs.

> Feminists have argued for the decentering of masculinity in society's thoughts and practices: no longer should manliness (however that is culturally defined) be

> the standard for the so-called human; no longer should masculinity and its widespread expressions across the canvas of cultural life be the preoccupation of everyone's anxious attention (Harding, 1991, p.13).

The gendering of science has made that which is masculine appear to be the canvas of science. The masculine viewpoint has dominated that which is deemed to be science. It is this domination of science that concerns the feminist science scholars. They question whether the mere inclusion of women in science is enough to make an impact on the field. Is there a masculine and a feminine viewpoint? If science had been dominated by women would its practices and philosophy be different?

The history of science tells us how difficult is has been for women to be included in science, viewed as a scientist, and given credit for accomplishments. It is these issues that plague feminist science scholars. From the women in history who were excluded from the Nobel Prize to those whom we have no record of existing, women have had to fight for recognition in a field that even today is an unwelcoming venture for many women. The equity issues run deep in the core beliefs of science. Harding discusses that mere reforms may not be enough to bring about needed changes.

> …[M]ere reforms of science cannot possibly resolve the equity issues. Instead, it appears that there will have to be revolutionary changes in social relations between the genders and in science's relationship to the societies that support it before it is no longer regarded as a contradiction in terms to be a woman scientist (Harding, 1986, p.68).

Reforms to include more women in science are not enough to bring about revolutionary changes in social relations between the genders. Merely being included in science as a

participant is not the same as contributing to its structural design and philosophy. Only by the inclusion of various viewpoints can science avoid becoming elitist.

CHAPTER 4

TEXTBOOKS: HOW SCIENCE CREATES REALITY

Textbooks are political. The information contained within the text are subject to negotiation and approval by a select body of individuals, but to the general population textbooks contain truth. Understanding this negotiation of the truth opens the door to understanding the state of our knowledge. According to Kuhn (1996):

> For reasons that are both obvious and highly functional, science textbooks (and too many of the older histories of science) refer only to that part of the work of past scientist that can easily be viewed as contributions to the statement and solution of the texts' paradigm problems. (p. 138)

Information and contributors outside of the mainstream are denied entrance into texts for the next generation. Textbooks, a major income source for several multinational corporations, must negotiate the political process of textbook adoption in order to gain access to massive sums of money. Textbook authors sanitize subjects in order to complete the adoption maze. Part of this sanitization process includes removing all but the generally accepted icons of the field.

Textbooks are secondary sources used to teach the reader all that is paramount in the subject. It contains both fragmented information and interpretation.

> Despite the classroom primacy of the textbook, it is the paradigmatic secondary source. To be more precise, the textbook is emblematic of performance of two kinds of work: the "extraction" of the "main concepts" of some primary source

> and the clear "explanation" of them. The textbook is the end product of a "correct" reading of primary sources. (Aoki & Jackson, 2007, p. 1)

It is in the extraction of information and its subsequent interpretation in the textbook that leads the reader to generalize its contents as being exclusive of the subject.

Texts are not objects incapable of producing harm. The texts created by a culture provide insight into the norms and mores of the society.

> Books and stories have long been a method used to teach children what is acceptable and expected in their culture. When the books used present a biased picture, the children using them do not develop a variety of possibilities for their life. (Gail, 1996, p. 3)

To the child, the texts presented are accurate portrayals of the world. They serve as guides to the world beyond their personal experiences and can either present the world as a place of endless possibilities or limited by factors beyond the child's control. In today's world, textbooks present a limited world. Doll (2000) states, "Textbook 'writing' only serves to keep the imagination thin" (p. 28). According to Gardner (1991), the schemata created during these earlier experiences will significantly influence the individual's outlook for the remainder of life. In the case of the child interacting with text that belittles or fails to mention the subset of the population of which the child is a part, the individual forms schemata that limit possibilities. The following statement by Sadker and Sadker (1995) expresses a similar concept. "Each time a girl opens a book and reads a womanless history, she learns that she is worth less" (p. 9).

According to Michael Apple (1993) this discussion "opens the door to the most important question we can ask about our schools: Whose knowledge should we teach?"

(p. 5). The typical answer for most texts is a male centered view of our world. The gender- biased nature of these text are undetected by most of its readers- teachers and students. Sadker and Sadker (1995) describe gender bias as "a syntax of sexism so elusive that most teachers and students are completely unaware of its influence" (p. 2).

While the gender bias present in textbooks typically escapes the end users, teachers and students, it has not avoided notice by all.

> School books shape what the next generation knows and how it behaves. These textbooks segregate sexes by displaying predominately male role models. When women and minorities are under represented in curricular materials, it implies that these groups are of less value and significance in society. (Edgar, Fisher, Martin, & Morris, 1997, p. 11)

The standards-based approach to education has advocated the move away from textbooks as the driving force of the curriculum but this change in mindset is far from complete. "Textbooks tell a great deal of the story of science education. They have been and remain both the medium and the message in elementary and secondary science" (Bianchini, 1993, p. 7). Textbooks still remain the guide in the majority of science classrooms in the United States (Budiansky, 2001; American Association for the Advancement of Science, 2007). The materials presented in these texts are considered the sacred materials of the field.

In 1992, the American Association of University Women Educational Foundation published *How Schools Shortchange Girls.* In this work, the foundation called for reform to dispel the myth that math and science fields were inappropriate for women and called

for an increase in the amount of female role models in science, technology, engineering, and mathematics curriculum (Morse, 1995).

There are many forms of bias that are found in our nation's textbooks. Zittleman and Sadker (2003) have identified seven forms of bias in curriculum material: 1) invisibility, 2) stereotyping, 3) imbalance and selectivity, 4) unreality, 5) fragmentation and isolation, 6) linguistic bias, and 7) cosmetic bias. These biases, present in varying amounts in textbooks, pass on messages, either overt or covert, to the reader.

Invisibility refers to the omission of individuals of a particular gender, sex, race, or ethnicity in a text. Prior to the 1960s, textbooks in the United States focused solely on the white male. Since this time, strides have been made to include the contributions made by African Americans and Latinos in school science texts. Unfortunately, with the exception of Marie Curie, females still fail to appear in a substantial way in science textbooks commonly used in the United States.

The omission, or invisibility, of females in science textbooks reinforces the view that only males are capable of performing scientific explorations of note. By ignoring the valuable contributions made by female scientists, textbook publishers fail to provide role models for subsequent generations of females. The lack of same sex role models in the sciences has been reported by women as a major deterrent to pursuing a career in chemistry, physics, and engineering (Packard & Wong, 1999; Hammrich, Richardson, & Livingston, 2000; National Academies, 2007).

The presentation of stereotypical portrayals has been both an overt and covert form of bias in textbooks for centuries. The repeated presentation of stereotypical images and text has been linked to significant damage to the human psyche and performance level.

> The stereotypes we accept about sex roles have far-reaching effects. Ideas about appropriate behavior for women and men act as powerful constraints on behavior and often become self-fulfilling prophecies" (Lowe, 1982, p. 91). "To grow into well rounded adults who are able to utilize all of their potential, children need exposure to a myriad of possibilities from a wide variety of models that give many different visions of opportunities and ways of behaving" (Gail, 1996, p. 4).

It is the exposure of women scientists as role models that helps combat the stereotypes of the field as being for males, which is commonly portrayed in textbooks. It is these stereotypes that send female students the message that science is a male field. It is the stereotypical images in textbooks that contribute to women not identifying with science. The overt use of gender stereotypes in science textbooks have decreased since the 1960s. The covert use of stereotypes to reinforce the image of science as a male field has not disappeared from science textbook publishing. Currently, images of males and females appear in near equal numbers in science textbooks but there are significant differences in their portrayal. Males are portrayed as active members in the scientific process. They are engaged in the act of doing science. In texts, males are frequently seen in the laboratory or in the field actively seeking new discoveries. Females are passive onlookers. Science is being done around them. The female reader receives the message clearly. Females are to be passive observers of science; males are the active force behind scientific discovery.

Imbalance and selectively refers to simplification or distortion of complex issues. In science texts, the stories and viewpoints of female scientists have been distorted to reinforce the belief that females are not capable of performing independent scientific studies but must labor under the direction of a male.

Many texts present an unrealistic view of the past. Textbooks are notorious for "glossing over unpleasant facts and controversial events" (Zittleman and Sadker, 2003, p. 7). The theft of scientific breakthroughs from females, such as the x-ray pictures of DNA produced by Rosalind Franklin which provided foundational evidence for the double helix structure of the molecule proposed by Watson and Crick, is not mentioned in the vast majority of science text. Watson and Crick stand alone in the discovery of the molecule of life and became giants mentioned in every introductory life science text in secondary schools, colleges, and universities. Rosalind Franklin failed to share in the fame and fortune which was so rightfully hers, and today's young women are effectively denied the opportunity to gain from her story.

The demand for more inclusive texts that has swept the nation over the last thirty years was too powerful of a force for textbook editors and publishers to ignore. In order to appease the feminists a handful of women have been added to science texts. However, when females are mentioned in science texts, it is often in a fragmented or segmented manner. The female scientist becomes the sidebar at the end of the chapter and not part of the main content in the curriculum. For example, in a recent text, Rachel Carson's name is presented only in a timeline sidebar while the work of Cousteau is presented prominently in the body of the text. She is merely a sideshow. Segmenting women from the main text presents them as "peripheral, less important than the main text" (Zittleman & Sadker, 2002, p. 8).

The power of the written word on the formation of gender biases has been identified by numerous researchers. The use of the pronoun "he" works to exclude females from

consideration. In the last twenty years, authors and publishers have worked diligently to remove linguistic biases from textbooks.

Finally, cosmetic bias results when publishers make minor alterations to texts to reduce or avoid accusations of gender or racial bias. These surface changes typically consist of an increase in the number of females displayed on the cover or inside the text. At first glance it will appear that it has given significant representation of females in scientific fields, but on closer examination, the text fails to delve into the significant contributions made by females throughout the history of science.

Contrary to popular belief, science is not an all knowing independent entity that has more credible evidence than other disciplines, despite the common use of the term 'scientific evidence' to proclaim the utmost in proof. All knowledge is subject to human influence and is therefore a type of narrative knowledge. Postmodern thought examines science as a form of narrative knowledge.

> The fact is that the Platonic discourse that inaugurates science is not scientific, precisely to the extent that it attempts to legitimate science. Scientific knowledge cannot know and make known that it is the true knowledge without resorting to the other, narrative, kind of knowledge, which from its point of view is no knowledge at all. (Lyotard, 2002, p. 29)

Science cannot deem itself to be true knowledge over other perspectives due to the fact that its attempts to legitimate itself are embedded in narrative knowledge. How can science claim to be a more legitimate form of knowledge than simply a narrative?

Science is as vulnerable to myth making and fabrication as any other form of knowledge. In examining the many outlandish scientific theories in the history of science

that were accepted as truth, one can understand that science is actually embedded in mythos and folklore, passed down from generation to generation and never questioned.

> Mythos is the knowledge and ways of knowing associated with cultural myth, a knowledge and knowing that take things for granted as the way they naturally should be. (Carlson, 2002, p.6-7)

The stories of science are filled with cultural myth. It's these myths that influence the truths that science creates. It is the belief in these myths that influences society to accept them as truth. Scientific proof is thought to be beyond human error. However, this knowledge can never be independent from the observer and their representations. Scientists are not independent observers devoid of preconceived notions and agendas.

> Biologists are not ventriloquists speaking for the Earth itself and all its inhabitants, reporting on what organic life really is in all its evolved diversity and DNA-soaked order. No natural object-world speaks its metaphor-free and story-free truth through the sober objectivity of culture-free and so universal science. (Haraway, 1997, p.217)

Scientists are not direct conduits of the Earth's knowledge. The gathered information must pass through the scientist and is vulnerable to the construction of the human mind. It is this influence that science denies exists when it proclaims its findings fact with the exclusion of other beliefs. Western science has proclaimed its science the one true belief system and that its methods are superior to those of other cultures. The history of science is filled with these cultural myths and beliefs in the definitive authority of the scientist. "Any institutionalized method for producing knowledge has its foundations in social conventions: conventions concerning how the knowledge is to be produced, about what

may be questioned and what may not, about what is normally expected and what counts as an anomaly, about what is to be regarded as evidence and proof" (Shapin & Schaffer, 1985, p. 225). The scientific method is an institutionalized method for producing knowledge. The creation of scientific knowledge is believed to provide proof because of the socially accepted convention of the scientific process.

Most of what children learn in the school curriculum is believed to be factual. Curriculum planners work to prioritize the information necessary for students to develop into productive members of society. This belief ignores the relationship between ideology and what is determined to be important in the curriculum.

> Once the relationship between schooling and the larger society is recognized, questions about the nature and meaning of the school experience can be viewed from a theoretical perspective capable of illuminating the often ignored relationship between school knowledge and social control (Giroux, 1988, p. 22).

School knowledge is directly connected to that which is deemed important to the dominant class. Curriculum has been influenced considerably by the dominant culture. The commonly held belief that the school curriculum contains entirely factual based information is an incredible miseducation. Curriculum is influenced by the dominant cultures' viewpoint and how it chooses to represent itself. "The school curriculum communicates what we choose to remember about our past, what we believe about the present, what we hope for the future" (Pinar, 2004, p.20). The political influence on school curriculum is the driving force behind its misconception. Teaching curriculum as a factually based venture with its importance placed on answers rather than questions makes it a closed minded system that does not encourage children to think for

themselves. The focus isn't on understanding curriculum instead in a regurgitation of it. It is this miseducation that leads to students to become Eurocentric and intolerant of other cultures beliefs.

Within the domain of education it is commonly believed that what one is taught is that which has significant value. Who determines that which has significant value? "In the banking concept of education, knowledge is a gift bestowed by those who consider themselves knowledgeable upon those whom they consider to know nothing" (Freire, 1970, p.72). The science curriculum is used to educate students about more than scientific facts. It teaches them what the dominant class believes to be important. Men are glorified in the field and are given priority in the historical text. The omission of women in the main text teaches students to believe that women have played a minor role if any in science development. This lack of representation teaches students that women are not as interested in the field of science. This in turn affects how girls may perceive their own place in science. This is often perceived to be women not having an interest in the field when their lack of interest is actually because of the way the material is being presented to them.

CHAPTER 5

MARIA MITCHELL

> These immense spaces of creation cannot be spanned by our finite powers; these great cycles of time cannot be lived even by the life of a race. And yet, small as is our whole system compared with the infinitude of creation, brief as is our life compared with cycles of time, we are so tethered to all by the beautiful dependencies of law, that not only the sparrow's fall is felt to the outermost bound, but the vibrations set in motion by the words that we utter reach through all space and the tremor is felt through all time. (Maria Mitchell, 1896, p. 35)

The life of Maria Mitchell resembles the comet that bears her name- a bright burning light (the first person to record a comet sighting, the first woman appointed to the Academy of Arts and Sciences, the first woman named to the American Association for the Advancement of Science, the first woman professor of astronomy in the United States) that quickly passed from sight. While Mitchell's name has not joined the pantheon of Ptolemy, Brahe, Galileo, Copernicus, Kepler, and Halley, the ripple effect created by her work changed the course of numerous lives.

In writing of Maria Mitchell, Harriet Townsend, in *Reminiscences of Famous Women*, (1916) stated, "It would be impossible to overestimate the value of such a life, its seed still prospers and blossoms as the rose" (p. 132). Maria Mitchell not only succeeded in a time where women were seen as generally inferior but in a field viewed as beyond the limited mental capacity of her sex, and unlike many women of her time who wished to participate in fields assigned a masculine label, Mitchell did not hold her tongue. "Lest

we forget is a pertinent watchword far too little heeded, as we push on to realize what some believe to be new and better ideals of womanhood" (Mitchell, 1868, p. 92).

In 1865, Vassar Female College opened with thirty faculty members and nearly four hundred students. Mitchell, the first professor hired for the Vassar faculty, became the sole member of the department of astronomy. For the next 23 years, until shortly before her death, Mitchell served on the faculty of Vassar and as the spark to dozens of women's careers in the sciences most notably Antonia Maury (major contributor to the work that led to the Hertzprung-Russell diagram of star classification), Mary Whitney (professor of astronomy at Vassar and mentor to numerous women scientists herself), and Ellen Swallows Richards (environmental chemist and the founder of the scientific study of home economics). Upon her death in 1889, Anna Brackett, a fellow educator and advocate of women's rights, wrote of Mitchell:

> The special students in astronomy were never very many, but her influence was not confined to them. She took her meals in the large hall and was familiar with all the students, and wherever she appeared there blew a fresh breeze of genuine life. Clear and strong and pure as the sea breeze over the south shore of her native island, her personality made itself felt. Her absolute truthfulness of character never failed to find and fortify the honest intent. (p. 954)

Mitchell spread her passion and knowledge of science to several generations of Vassar students. Mitchell, no stranger to obstacles on the pathway to one's dream, encouraged her students to follow pathways where few women dared to tread.

Born in 1818, Maria Mitchell lived during a time period when the intellectual capabilities of women were not considered sufficient to perform scientific exploration.

The female brain was considered incapable of processing data and drawing conclusions. The male brain was deemed superior to that of a female. Despite the roadblocks consistently set in her way, Maria Mitchell persevered and proved those beliefs about women to be false. She blazed a path for others to follow.

Mitchell's love of the stars was nurtured from childhood by her father, a professional astronomer of some notoriety in his own right. William Mitchell took control of his daughter's education and ensured that her studies included biology, chemistry, physics, and astronomy. Determined to see their daughter receive an education beyond that typical of the time (sewing, housekeeping, basic mathematics and reading), Mitchell's parents enrolled her in Cyrus Pierce Academy, a school for girls that provided a rigorous curriculum including higher order mathematics and sciences. Mitchell, based on her intellectual prowess and academic abilities, quickly became a teaching assistant to the academy's founder, Cyrus Pierce, who would later open the first normal school in the United States. The position quickly began to bore Mitchell and diminished the time she had available to continue the study of her true passion, the stars.

In 1836, at the age of eighteen, Mitchell left the academy to accept the position of librarian at Nantucket's Atheneum Library. The new employment provided Mitchell ample time to search the skies above. Fortuitously, in the same year, William Mitchell completed the construction of an observatory at the family home. After closing the library, Mitchell would spend the evenings examining the sky. Over a decade would pass before she made the discovery which would change the course of her life.

On a cool evening in the fall of 1847, Mitchell gazed in the heavens through her most precious asset, a telescope constructed by the finest lens makers in the United States. On

this night, a new glimmering object entered her field of view. Taking great care to track the light's movement, Mitchell meticulously plotted the course of the object. Euphoria overwhelmed her as she realized the magnitude of her discovery. This little spot of light became the first comet to be identified by an American.

> From the time she burst into the national consciousness as the discoverer of Comet 1847 VI, she had been a model of what a woman, given the chance could accomplish in science. Those who claimed that a woman's brain would collapse under the strain of studying mathematics and science had been refuted by the very existence of Maria Mitchell. (Gormley, 1995, p.121)

For her discovery, Mitchell received accolades both nationally (appointment to the Academy of Arts and Sciences) and internationally (recipient of the Danish Royal Medal). The bright, shining object in the heavens changed the course of Mitchell's life on Earth.

While Mitchell gained recognition for the discovery of the Mitchell Comet, her accomplishment did not pass untarnished. Following quickly after Mitchell's identification of the comet, others laid claim to the discovery. Fortunately for Mitchell, William Bond, a Harvard professor and one of the foremost astronomers on the planet, supported the librarian's claims. William Mitchell had contacted Bond prior to any of the other individuals claiming the discovery. Yet, the controversy did not end with the establishment that the first sighting had taken place in America. The identity of the true discoverer was called into question. Critics claimed the true discovery of the comet's fiery trail laid with William Mitchell, Maria's father- his desire to see his young daughter succeed in the male-dominated field of astronomy leading him to attribute the finding to

her. The scientific leadership of the United States could not easily accept the possibility of such as significant discovery being made by a mere woman. Only when confronted with Maria's meticulous notes detailing her nightly observations of the heavens did the voices denying her claim quiet to a whisper

Denied the opportunity to pursue higher education due to both sex and socioeconomic status, Mitchell had regarded a professorship beyond her reach, but the fame afforded her by the comet's discovery presented new opportunities. Maria found herself barraged with offers of paid lectures and teaching positions. Unfortunately, Mitchell could not capitalize on this new found fame due to the fact that they would draw her away from home. As the eldest, unmarried female child, Maria was called upon to care for her ailing mother. While her exploration of the heavens would continue during this time period, her opportunities were severely limited in the village of Nantucket.

By 1865, Maria Mitchell's life had changed dramatically. Tragically, her mother had passed in 1862. While this was an emotional blow to Maria, it did free her to travel beyond the tiny village of Nantucket. Sensing the need for new challenges in her life, she began to search for opportunities that would allow her to combine two passions, astronomy and teaching. As fortune would have it, the chance to educate others in the stars would present itself in the form of Matthew Vassar.

Vassar, a self-made millionaire brewer from New York, had committed a considerable portion of his fortune to create an institution dedicated to providing opportunities for higher learning to women. The college, named after its founder, took four years to build due to the strains of the Civil War. In 1865, Vassar College opened with 353 students and thirty faculty including Maria Mitchell, professor of astronomy.

Vassar would serve as Maria Mitchell's home for the next twenty-three years. During her tenure, she presided over the development of the college's most significant asset at the time, it's observatory. The observatory, equipped with the third most powerful telescope in the country, was ruled over by Mitchell. Nightly, she educated the students of Vassar on the position and movement of celestial objects while keeping copious notes for research. Under her stewardship, Mitchell continued to expand the capabilities of the observatory through the use of her own funds. Today, the building bears her name. The Maria Mitchell Observatory continues to serve the students of Vassar. Unfortunately, the work of Mitchell has not.

In 1888, Mitchell retired from Vassar. While offered a permanent residence at the university, she declined and moved to Lynn, Massachusetts to be close to family. Her time there would be short. On June 28, 1889, Maria Mitchell passed. Her body was returned to her native Nantucket and interred on Prospect Hill, the highest point in the region. Fittingly, her grave now lies in the shadow of Loines Observatory, a facility devoted to sharing the stars with all.

As professor of astronomy at Vassar College, Mitchell encountered and encouraged hundreds of young women to pursue careers which inspired their souls and provided them self-sufficiency.

> When others, considering it 'unladylike,' were horrified by her revolutionary idea that all women, rich and poor alike, should be able to earn a living, she declared, 'I take great pride in the fact that I urge upon every girl who comes into my department the dignity of occupation.' (Gormley, 1993, p. 114)

Mitchell was not satisfied with preparing future generations of women to become good wives and mothers. Her calling was to prepare women for careers outside of the home. To Mitchell, the accumulation of knowledge and skills would release women from the bonds of servitude to man. On this issue of educating young women for future places in society, Mitchell (1896) stated, "I would as soon put a girl alone into a closet to meditate as give her only the society of her needle" (p 40). According to Mitchell, the mundane household tasks that women were normally relegated to amounted to servitude. Women were to be explorers of the world around them and equals to men in the realms of science. Mitchell wanted women to expand their horizons and move beyond the common work of the home and into the laboratories and field to examine the natural wonders of the universe.

Mitchell, through the power of her personality and dogged determination to resist the status quo, motivated a cadre of educated women to challenge the power structure in existence at the time.

> She spoke graphically of science and the nature of scientific method, of the way to good scientific teaching; and women in her audience who still clung to the belief that woman's place was in the home stirred uneasily and found themselves wondering whether they too should not go out and study nature. (Wright, 1949, p. 202)

Mitchell viewed education and a subsequent career as the road to economic and political freedom for women. Mitchell believed that without the power of higher order thinking skills and gainful employment women would remain subservient to men in all regards.

While Mitchell's work at Vassar was significant, her work outside of the halls of higher education may have had a more profound effect on society through her efforts as a political advocate. In 1873, Mitchell, with Elizabeth Cady Stanton, the author of the *Declaration of Sentiments* and co-organizer of the Seneca Falls Convention of 1848, founded the Association for Advancement of Women (AAW). The purpose of the organization was to increase women's work opportunities outside of the home (Rossiter, 1982). Mitchell served as both the president (1874-1876) and chairperson of the committee on science for the AAW. In both roles, Mitchell reported the state of women in the sciences and methods to improve the position of the sex in these fields. In her 1875 presidential address to the association's annual Congress of Women, Mitchell (1896) stated:

> In my younger days, when I was pained by the half-educated, loose, and inaccurate ways which we all had, I used to say, 'How much women need exact science,' but since I have known some workers in science who were not always true to the teachings of nature, who have loved self more than science, I have now said, 'How much science needs women.' (p. 1)

At the time, this statement was considered extremely radical in nature. Science was (and indeed, is) a field for men. Women were identified as intruders to the laboratories and research facilities not as functional and necessary components of scientific endeavors. Mitchell's statement illuminated the need for women to contribute their unique viewpoint to science. To not allow this contribution would diminish the fields of science and would be a detriment to all.

> Until women throw off reverence for authority they will not develop. When they do this, when they come to truth through their own investigations, when doubts lead them to discovery, the truth they get will be theirs, and their minds will go on unfettered. (Mitchell, 1896, p.17)

According to Mitchell, the sciences would be vastly improved by providing for the full inclusion of women. The sciences were consistently being corrupted by individuals (males) seeking self-aggrandizements and not the advancement of human knowledge. To Mitchell, the pursuit of scientific knowledge would be greatly benefited by the multitude of perspectives provided by her gender. Mitchell's comments foreshadow the work of Sandra Harding and Evelyn Keller. Science should not only allow women to freely enter the ranks of researchers and academics as a gesture of equality but suffers by denying the feminine perspective. Harding (1991), in her groundbreaking text *Whose Science? Whose Knowledge? Thinking from Women's Lives*, states:

> Why is this gender difference a scientific resource? It leads us to ask questions about nature and social relations from the perspective of devalued and neglected lives. Doing so begins research in the perspective from the lives of "strangers" who have been excluded from the culture's ways of socializing the "natives," who are at home in its institutions and who are full-fledged citizens. It starts research in the perspective from the lives of the systematically oppressed, exploited, and dominated, those who have fewer interests in ignorance about how the social order actually works. (p. 23)

Mitchell's strident demands for increased opportunities for women cannot be described as the norm. Women involved in precarious academic and research positions

failed to speak out against the inequalities present in the system. According to Keller (1991):

> During the late nineteenth century, the strategies used by women who aspired to enter the world of science were often aimed more toward accommodation than toward equity. As such, they might be described as "preliberal." Many women scientists resigned themselves to (or sometimes actively sought) a secondary demarcation within the realm of science. (p. 271)

The vast majority of women involved in scientific pursuits were willing to accept the scraps allowed to fall into their hands. The cost of the meager employment opportunities, materials, and facilities provided to them was silence. Mitchell refused to accept this price. Her voice could not be silenced by threats of banishment from the academy and seizure of the minimal research facilities provided to her.

As Mitchell's life drew to a close, the quiet demands for equality began to rise to a shout. Rossiter (1982) stated the following regarding the end of the 19th century:

> Now that women were being as well educated as men and were holding jobs, although marginal ones, in science, the remaining limits to their full equality, formally accepted as inevitable, began to seem intolerable. The root of this new impatience and anger was the political doctrine of feminism, or the view that women were the equal to men and that any social constraints preventing this should be changed or abolished. (p. 101)

The impatience, anger, and hope for a different social structure are typically presented as faceless and nameless. The movement which increased the political and economic opportunities of women was populated by individuals such as Mitchell. Maria Mitchell

was at the forefront in the struggle against the social constraints impeding the progress of women.

> We all have world views-a complex web of ideas, values, and assumptions about how the world operates. We all have certain fundamental beliefs, for example, about whether people are naturally generous or greedy, or whether we are the victims of our fate or controllers of our destinies. (Tichy, 1997, p. 59)

Bandura (1997) defined self-efficacy as the "the beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 2). High levels of self-efficacy have been correlated to high levels of achievement and task persistence. Additionally, individuals who have made notable discoveries and inventions have been shown to have significant levels of self-efficacy. In contrast, Bandura (1995) found:

> People who have a low sense of efficacy in given domains shy away from difficult tasks, which they view as personal threats. They have low aspirations and weak commitments to the goals they chose to pursue. When faced with a difficult task, they dwell on their personal deficiencies, the obstacles they will encounter, and all kinds of adverse outcomes rather than concentrate on how to perform successfully. (p. 11)

When encountering tasks with roadblocks, individuals with low levels of self-efficacy refuse to engage the task. The risk of failure is overwhelming. Refusing to engage in the task protects the individual's sense of self-worth however limited that sense of self-worth might be.

One's level of self-efficacy has been linked to four key factors: one's own successes and failures in the past, the successes and failures of a person in a similar situation to oneself, information given to the subject from others about the level of risk and reward a particular situation entails, and one's emotional and mental strengths weaknesses (Zeldin & Pajares, 2000). As one finds persons in similar situations to oneself becoming successful, the individual's level of self-efficacy grows. Mitchell, a woman faced with significant barriers to gain entrance to the scientific community, provides a role model for other women seeking a place in the male world of science. Her life was an example of how much a woman could accomplish in science.

Role models are powerful forces in the development of an individual's character. Positive role models have been tied to high levels of self-efficacy (Nauta & Kokaly, 2001).

> There is a powerful human tendency to gravitate towards people who remind us of ourselves. People who are in some way similar make us feel safe: We understand their motives, we share some of their experiences. And because we anticipate that they will see some of themselves in us, there is less fear of rejection. (Steele, 2002, p. 18)

In nontraditional fields such as mathematics, chemistry, astrophysics, and engineering, female role models are limited and the lack of role models has been identified as a barrier to entry into these professions (Betz, 2002; Quimby & DeSantis, 2006). A significant number of women pursuing careers in these fields have identified their fathers as a source of encouragement and a role model. Mitchell herself falls into this category. Encouraged by her father, Mitchell saw astronomy as a valid and achievable career for a female.

Positive role models increase self-efficacy by combating the power of the stereotype to guide decision-making. According to Freire (1970):

> Many persons, bound to a mechanistic view of reality, do not perceive that the concrete situation of individuals conditions their consciousness of the world, and that in turn this consciousness conditions their attitudes and their ways of dealing with reality. (p. 130)

One's actions are heavily influenced by the paths that are seen as possibilities. Possibilities become conditioned by the view of reality one is confronted by on a daily basis. Without the presentation of alternatives, the future becomes prescribed. The presentation of a full menu of possibilities opens the mind. Maria Mitchell penned the following words, "We have a hunger of the mind which asks for knowledge of all that's around us, and the more we gain, the more is our desire; the more we see, the more we are capable of seeing" (Mitchell, 1898, p.1). The provision of alternatives to the official curriculum and text, including female role models in science, opens the eye and the mind to an entire world or possibilities.

The war waged by Maria Mitchell over 100 years ago continues today. According to the National Center for Education Research (2007) guide, *Encouraging Girls in Math and Science*:

> There are many negative stereotypes about women in science. They include the perceptions that women should not be scientists, that women lack certain analytic and cognitive abilities that are essential to working in the sciences, that girls need not learn as much higher level mathematics as boys; and that girls are innately more interested in the arts and humanities, whereas boys' interests take them to

> more technical pursuits. There is also a belief that science and mathematics are rare, innate abilities. Simply put, some people believe that only some can do science and others cannot. (p. 1)

The work, written to highlight the roadblocks faced by women attempting to enter science, mathematics, and engineering fields, could have easily originated from Mitchell's pen. Women continue to be viewed as less capable in mathematics and science than their male counterparts. Mitchell's life and work are testaments to the fact that women are capable of performing science at high levels and spurring others to these pursuits.

Unfortunately, the story of Maria Mitchell is not being taught as a part of the official curriculum to future generations of potential women scientists. A review of current textbooks in earth and space science reveal that Maria Mitchell's life has been identified to be irrelevant. The four largest textbook publishers (Pearson, McGraw-Hill, Houghton-Mifflin, and Harcourt) do not cite the work or mention the impact of Mitchell's life on the scientific development of the United States while male scientists with equal contribution and impact (Hubble, Kuiper, Shoemaker) are mentioned in multiple texts. Eugene Shoemaker, a scientist whose career mirrors that of Mitchell in many ways (i.e., discovery of a comet, dedication to the exploration of the universe, a lifetime of recording the movements of the universe), is prominently mentioned in more than one general earth and space science textbook. While the work of Shoemaker is certainly noteworthy, it does not warrant his inclusion in text while Mitchell is excluded.

The exclusion of Mitchell (and a plethora of women scientists who have made significant contributions to science) from today's textbooks has had substantial impact on

future generations of potential scientists. Viewing others like oneself as powerful and world changing is an altering experience. “To go beyond defining ourselves as victims of male power and domination, we have to acquire the sense that our individual histories and needs, as well as our collective experiences and actions are important” (Hubbard, 2001, p. 50). According to the Commission on the Advancement of Women and Minorities in Science Engineering and Technology Development (2000):

> One reason that female, underrepresented minority, and disabled children- as well as the adults who support them- don’t think of science as a career to which such children can aspire, is that people who look like them are seldom portrayed as scientists. (p. 54)

The power of providing role models is undeniable. The ability to see that a potential “line of flight” is possible adds to an individual’s self-confidence and self-efficacy. According to Egan (1989):

> We can see the importance of human emotions and intentions in making things meaningful. To present knowledge cut off from human emotions and intentions is to reduce its affective meaning. This affective meaning, also, seems especially important in providing access to knowledge and engaging us in knowledge.

While the content knowledge must be presented as a part of the curriculum, the absence of the affective is detrimental. The affective is what drives one towards a goal. In the case of Maria Mitchell (and a multitude of women scientists), the affective component of the educational process has been excluded. The content knowledge is presented without context. The human nature of the science is excluded.

CHAPTER 6

ELLEN SWALLOW RICHARDS

In 1955, the work of Dr. Jonas Salk was revealed to the world. Salk, who developed a vaccine for polio based on dead virus particles, has been hailed as a miracle worker. The physician, a humanitarian and true pioneer in immunology, became a household name across the United States. He became the man who made it safe for children to play outside during the summer again.

Nearly seventy years prior to Salk's work, another scientist bent on improving the public health made a breakthrough discovery. In the 19th century, public water supplies were a transportation system for disease-causing organisms. Cholera, malaria, typhoid, and a variety of gastrointestinal diseases quickly spread throughout a population via water. In 1886, the Massachusetts State Board of Health petitioned the fledgling Massachusetts Institute of Technology (MIT) to examine water quality across the state and investigate new water testing methods. The method commonly used, injecting samples under the skin of a rabbit and observing the prognosis of the animal, was viewed as archaic, inhuman, and time consuming (Vare, 1992).

The situation across Massachusetts was dire. Thousands of its citizens fell victim to the plagues carried by water every year. Dr. George Derby, the commissioner of the Massachusetts State Board of Health described the condition of the time and his prediction for the future with the following words:

> The pollution of streams by industrial establishment and by the sewage of towns has been several times during the past year brought to our attention. Judging from

> the history of still more densely populated manufacturing areas in other parts of the world, the general subject will continue to claim the attention of the people of Massachusetts for many years to come. (Derby in Clarke, 1973, p. 37)

The rapid industrial "advancement" of the period placed a huge burden on the human population and the surrounding environment. The major population centers in Massachusetts were in constant fear of the next wave of disease that would pass through the cities via the polluted water systems and streets.

Over the course of the next two years, work conducted under the auspices of MIT "led to the establishment of water-quality standards modern sewage treatment plants" (Chemical Heritage Foundation, 2007, p. 1). Ellen Swallows was the chemist who discovered that testing for chlorine levels in water would yield valid results on potability. Her creations, the Normal Chlorine Map and water purity tables, remained in use for decades (Thompson, 1994). Furthermore, her studies on the treatment and release of sewage back into the environment led to environmental mandates across the state of Massachusetts.

The standards and treatment plants quickly led to a reduction in the number of disease outbreaks caused by water-born illnesses. The methods produced by the MIT-based researchers were adopted by numerous entities responsible for the provision of water to the public. While publicly headed by Dr. William R. Nichols, the true force behind the significant study was Ellen Swallow Richards. She should be known as the woman who made it safe for children to drink water in America.

Ellen Henrietta Swallow was born in 1842 to a family of modest means. Born in a time when higher education for women was seen as a novelty, Swallow faced

considerable hurdles to completing a college degree. Being from a family of modest means, funds to pay for attending university were not available to Ellen. An accomplished and determined student, Swallow refused to allow the scarcity of money to distract her from her dream, a higher education in the sciences. For ten years following the end of her formal secondary education, Swallow worked in various occupations and carefully saved her meager salary so that one day she could achieve her dream.

In September of 1868, Ellen Swallow entered Vassar College. Classified as a special student due to her age (twenty-six) and advanced abilities, Swallow participated in an accelerated program which allowed her to graduate in two years. During her time at the college, Swallow became the protégée of Maria Mitchell, Vassar's outspoken and determined Professor of Astronomy. Mitchell would serve as a force in Swallow's life for decades to come but, but she would diverge from her mentor on two issues.

Richards found the study of astronomy too detached from the needs of society. She wished to pursue scientific studies that could be put to use by the population-at-large.

> To Ellen, science was like a language. It had a literacy all its own. In a world being changed by science and technology, she saw a need for ordinary people to have some basic grasp of what language- if not its command- if they were to have some say in their own destines. She appointed herself responsible for translating the elite language of science into a vernacular for everyday use. (Clarke, 1973, p. 47)

Richards found the study of chemistry, with its multitude of uses to the everyday citizen, to be her passion (Thompson, 1994). Richards' studies focused on the positive use of the rapidly developing field of chemistry on what she considered the center of society- the

household. While Richard's work has often been placed outside the realm of the hard sciences, her work applies the concepts and content of chemistry to the health and safety of the family.

In the charged climate of her times, joining the suffrage movement could have caused significant damage to her scientific career.

> I hope in a quiet way that I am winning a way that others will keep open. Perhaps the fact that I am not a radical nor a believer in the all powerful ballot for woman to right her wrongs is winning me stronger allies than anything else. (Richards in Vare, 1992, p. 120)

While her mentor, Mitchell, would become a leader in the suffrage movement, Richards chose to fully commit herself to the academy. Richards identified the politics of gender as a source of great concern to the male-dominated administration of her institution of higher learning and therefore a potential hazard to expanding her ability to search for scientific knowledge and the sharing of knowledge with other women. Confronted with the realistic possibility of losing her tenuous position in the male realm of science, Richards shunned away from the hard stance for equal rights for women taken by her mentor, Mitchell. The choice was one that many women were forced to make during this time period and still is a problem in today's society. Presenting a strong opinion which runs contrary to the power structure has forced many women and people of color out of university, corporate, and research positions while male counterparts holding and stating opposing views remain.

While Swallow Richards has been attacked for remaining quiet on the issue of women's rights, her work advanced the understanding of humankind's impact on the Earth.

> To make the most of her own powers for the sake of using them in advancing knowledge and in broad and enlightened activity seemed to be her aim, while no opportunity from fellow service was to let slip by the way. (Hunt, 1958, p. 23).

Upon her graduation from Vassar, Swallow began a search for employment within the chemical industry. The search was in vain. Chemical companies had no desire to hire a woman chemist. Faced with few options, Swallow applied and was granted admission to the undergraduate program in chemistry at the Massachusetts Institute of Technology, the university that would play a major role in the remainder of her life.

> The faculty are of the opinion that the admission of women as special students is as yet in the nature of an experiment, that each application should be acted on upon its own merits, and that no general action or change of the former policy of the Institute is at present expedient. (Massachusetts Institute of Technology, 1871, p. 1)

She matriculated to the university in 1871 and completed the requirements for a bachelors of science degree in chemistry in 1873. In the same year, Swallow presented a thesis to her alma mater, Vassar College, and was awarded a master's degree in chemistry.

Armed with a master's degree, Swallow proceeded to seek admission to the doctoral program in chemistry at MIT. While she had produced outstanding results in both the classroom and laboratory at the institution, silence was the only answer from MIT.

> She was treated for some time as a dangerous person… It seems to me that some of the difficulties may have arose from the fact that the heads of the departments did not wish a women to receive the first D.S. in Chemistry. (Clarke, 1973, p. 44)

The Massachusetts Institute of Technology feared irreparable harm to its reputation if the first doctorate in chemistry was awarded to a woman. As a new institution of higher learning, John Daniel Runkle, president of the college, refused Richards admission. Now tied to MIT through work and marriage, Richards ended her dream of obtaining a doctorate.

Swallow's educational achievements are remarkable considering the barriers confronting her. Swallow lacked the financial resources to enter college upon completing her secondary studies. Determined to obtain a university degree, Ellen Swallow labored and saved the necessary funds to cover the tuition of her first year at Vassar. She would continue to struggle financially for the remainder of her time at Vassar.

More significantly, Swallow faced social barriers to pursuing a degree in the sciences. Women were not only considered incapable of performing the mental skills necessary to produce scientific knowledge but the act of thinking critically had been "proven" to cause harm to the mind and body of the fairer sex.

> Women were sternly warned that any effort to hone their inferior brains, particularly in science, would lead to damage both to themselves and their unborn children. Over-activity of the brain during the critical period of the middle and late teens will interfere with the full development of the mammary power and the functions essential for the full transmission of life. (Eisenberg in Thompson, 1994, p. 4)

The strain placed on the body by committing such an unnatural act as educating the female brain would interfere with the true role of women in society- the bearing of children. This line of thinking placed both women seeking education and the colleges willing to accept them in a precarious position.

In 1876, Ellen Swallow Richards followed in the footsteps of her mentor, Maria Mitchell, by committing her time and energy to educating young women in the sciences. Richards, with the aid of her husband's significant influence, orchestrated the opening of the Woman's Laboratory on the campus of the Massachusetts Institute of Technology. She served as the unpaid assistant director of the laboratory. She was the true force behind the institution, but could not serve as the laboratory's director due to her sex. A woman could not lead an organization dedicated to producing and disseminating scientific knowledge at a co-educational institution of higher learning. While Richards served as the force behind the creation and maintenance of the first laboratory solely dedicated to educating women, she was not considered an acceptable candidate for director of the project. In fact, Richards was not deemed worthy of being a paid employee of the Women's Laboratory. Her dedication to the education of women in the sciences led to her decision to volunteer her time and donate significant sums of money to the institution. Vare (1992) describes:

> There was a run-down old building in back of the Institute, a workshop that no one used. By volunteering to raise the money for the equipment, to teach for no pay, and to keep the place clean herself, Ellen was able to convince the Institute to turn the building into a chemistry lab for women. (p. 65)

While the facilities and equipment available to the students of the Women's Laboratory were substandard, the instruction provided by Richards was considered exemplary. For the next seven years, until the laboratory's closing, Richards provided instruction in introductory to biology and chemistry to women. While the majority of the attendees were schoolteachers wanting to increase their science content knowledge for the classroom, several of Richards' students went on to pursue careers in various scientific fields. Ellen's noble experiment remained in operation until 1884 when MIT, needing the space for more classrooms due to its explosive growth, withdrew the use of the building.

The training provided by the Women's Laboratory to schoolteachers had a profound impact on classroom instructions, most notably in the Boston area. The schoolchildren received instruction grounded in up-to-date content knowledge by the teachers trained at the laboratory. According to Clarke (1973), "She started the development that would play a major if unstated role in the nation's course: arming public education with the subject and substance by which America would grow to international scientific and technological supremacy in the next century" (p. 53). Ellen Richards Swallows began a battle that would wage on for over one hundred years and cost the United States billions of dollars (through programs sponsored by Dwight D. Eisenhower Professional Development monies and National Science Foundation grants)- creating a pool of teachers competent in the sciences.

The shuttering of the Women's Laboratory was a blow to Richards. The daily demands of the laboratory had filled her life. Fortunately, following the closing of the Women's laboratory, Richards was provided an opportunity that would change the course of her life. The Massachusetts Institute of Technology announced the establishment of

the nation's first laboratory of sanitary chemistry with William R. Nichols as the director. Nichols, impressed with Richards' work at the Women's Laboratory, appointed her to the position of instructor at the fledgling unit of the college. She would throw herself into the work of the new venture and become a guiding force in ensuring safe drinking water and the creation of sanitary standards.

Richard's work at the laboratory of sanitary chemistry would result in numerous accomplishments which clearly impact our world today. According to Vare (1992), "If Ellen Richards were living now, we would call her a 'consumer advocate' and an 'environmentalist.' There is nothing old-fashioned about her ideas at all. In her quiet, friendly way, Ellen was a revolutionary" (p. 9).

Ellen Swallows Richards is generally regarded as the founder of home economics as a field of study. During her time at MIT as an instructor (largely unpaid and under the auspices of her husband), Richards brought to bear the scientific advancements of the day on the American household. Her numerous works in the area, most notably *The Chemistry of Cooking* (1882), *Home Sanitation: A Manual for Housekeepers* (1887), and *Euthenics: The Science of Controllable Environment* (1912), led to remarkable advancements in sanitation and safe food handling. But, Richards' scientific contributions were much further reaching than promoting the avoidance of cross-contamination during cooking.

> Ellen Swallow Richards went on to lay the groundwork for the science that the German biologist Ernst Haeckel defined in 1873 as oekologie- the study of organisms in their environment. But today, if she is remembered at all, she is

> thought of as the founder of home economics; credit for the founding of ecology goes to Haeckel. (Clarke, 1973, p. 43)

Richard's was not credited with laying the groundwork for the field of ecology. She was instrumental in organizing the body of knowledge that the field is based on. Her anonymity and lack of proper recognition for her contributions to the development of the field are correlated with both her sex and the controversial nature of her work.

> Only by rejecting, revising, or ignoring her work have the people of today been able to lose sight of her- the woman who founded environmental science a century ago. The oversight, not coincidentally, allowed people to proceed undisturbed with exploitation of the environment (Clarke, 1973, p.200).

Richard's work would ignite the United States Public Health movement. (Clarke, 1973). The recognition of her work in the field of science is sparse. The work that she accomplished and its subsequent effects on future environmentalists is immense. Richards' work examining the impact of humankind's technological development on the environment foreshadowed later claims to be made by Carson and Gore. Richards identified that progress was leading to the pollution of the Earth and causing subsequent harm to humans. Carson would expand upon Richards' linkage by examining the impact of human development on the entire ecosystem. Even the work done today by countless environmentalists, including former Vice President Al Gore, can be traced to the work of Ellen Richards. Gore, who writes of the impact of human's emittance of pollutant into the environment, parallels Richards' work on the impact of human's release of waste products into the environment.

In 1888, Richards served as the driving force behind the establishment of the Woods Hole Marine Biological Laboratory. The marine laboratory is dedicated to the exploration of the oceans. During the course of its existence, the laboratory has played a role in multiple significant discoveries. Currently, the Marine Biological Laboratory supports a staff of over 200 scientists involved in numerous areas of research.

Science is a socially defined concept. Inclusion and exclusion from the concept has no hard and fast boundaries but is negotiated. According to Harding (1991):

> What counts as science and what counts as a contribution are determined by how elites in science and society choose to define them. Feminists have argued that these definitions are self-serving and that they obscure the important contributions of women in all classes and races to the production of whatever cultures count as their best kinds of knowledge. (p. 27)

Science is accorded a sacred place in America. It is given legitimacy by its status as the ultimate pursuer of Truth. The knowledge is rarely questioned by the public for it has been scientifically proven. When the nearly omnipotent scientist, in conjunction with political, social, and economic institutions, has established an item of knowledge to be fact, the information becomes Truth. These Truths are then included in the science textbook, a powerful source of knowledge.

The truths added to the science textbooks are part of the official knowledge. According to Apple and Christian-Smith (1991):

> It is important to realize, then, that the controversies over 'official knowledge' that usually center around what is included and excluded in textbooks really

> signify more profound political, economic, and social relations and histories. Conflicts over texts are often proxies for wider questions of power relations. (p. 3)

While textbooks are portrayed as the best of our knowledge, they are not apolitical or removed from the social sphere. They are issues of constant debate and result from prolonged negotiation. The resulting product is a particular construction of reality.

> Yet textbooks are surely important in and of themselves. They signify- through their content and form- particular constructions of reality, particular ways of selecting and organizing the vast universe of possible knowledge. (Apple & Christian-Smith, 1991, p. 3)

It is the selection of possible knowledge that limits what the reader learns. Fragmenting knowledge by excluding alternate explanations constructs a reality that is limited.

What is included as science is constantly changing. Areas of exploration ignored and excluded from mainstream discourse of science can come to the forefront based on the dictates of the time.

> Nobody has discovered an eleventh commandment handed down from the heavens specifying what may or may not be counted as a science. Obviously the project of drawing a line between science and nonscience is undertaken because it emphasizes a contrast thought to be important. Belief in the reality of this demarcation is necessary in order to preserve the mystique of the uniqueness and purity of the West's knowledge-seeking. (Harding, 2001, p. 194)

The vast majority of Richards' work has been excluded from the discourse of science. The application of the principles of chemistry and biology to the processes of the home is

not accorded the respect of being a science. The field of home economics, dominated by women, has been pushed outside of science and is deemed merely women's work.

Exclusion from the mainstream definition of science manipulates funding, employment opportunities, and prestige. Work not deemed worthy of the name science receives limited funding from the federal government. The National Science Foundation (NSF), an independent federal agency charged "to promote the progress of science, to advance the national health, prosperity, and welfare, and to secure the national defense", is "the major source of federal backing" for research at colleges and universities in the United States. With a budget of nearly $6 billion, NSF grants provide substantial funding to the mathematics, science, and engineering programs at institutions of higher learning across America. The high levels of funding received by chemistry, physics, mathematics, and engineering faculty substantially increase the number of full time positions, including full professorships, awarded to these departments. Research assistants, grant writers, and clerical staff are added to bolster to work of the cash machines. In turn, the institution becomes capable of managing larger and larger sums of governmental research funds.

In fields not allowed into the club, funds are limited. Programs remain significantly under funded and incapable of adding faculty and staff positions necessary to perform quality research. Without significant and valuable research to point towards, the field remains at a near standstill.

The study of the social structure of the scientific community is part of the evaded curriculum. According to the American Association of University Women (2002), the evaded curriculum includes:

> matters central to the lives of students and teachers but touched upon only briefly, if at all, in most schools. These matters include the functioning of bodies, the expression and value of feelings, and the dynamics of power. In both formal course work and in the informal exchanges among teachers and students, serious consideration of these areas is avoided. (p. 361)

The explicit and covert barriers which women face in entering the male-dominated territory of science are part of the evaded curriculum. Social and political roadblocks to full participation are not considered appropriate material for the classroom. Science is presented as a field removed from the social structure of the larger community. The hunt for the Truth cannot be corrupted and manipulated. To present science in any other fashion reduces it to being buffeted by base human emotions. This is not an acceptable topic for the powers controlling the field.

The sciences are presented as neutral when all other indicators signal that it is not. That which is not examined will not become troubled. According to Giroux , "Progressive educators help students to reach conscientizacao (conscientization). Conscientization means breaking through prevailing mythologies to reach new levels of awareness—in particular, awareness of oppression, of being an object in a world where only subjects have power". As a part of this conscientization in science, the view of science knowledge as unmanipulated and pure should be cast aside. It is dangerous and flawed. The story of Richards reveals the constructed nature of our scientific knowledge. Exclusion and modification are rampant in the history of the pure and hard sciences. Freire states:

> To prescribe is to manipulate. To manipulate is to reify and to reify is to establish a relationship of domestication which may be disguised behind an apparently

> inoffensive façade. In this case, it is impossible to speak of conscientization. (p. 149)

The reduction of the work of Richards to a place of lesser importance by relegating it to a position of lesser importance than the hard sciences is a method of prescription. The scientific explorations of a woman are beneath the high minded ideals of the male dominated research complex. Richards' work, which has greatly benefited humankind, is made less by this prescription and therefore not worthy of study.

While the impact of placing Richards' (and thousands of others') work outside of science appears minor to some, the ramifications are immense. The flow of funds and positions of influence move towards the sciences and not to fields that have been marked as pseudo-science.

> The unseen and untried have ever lured adventurous and courageous spirits, calling forth in every age explorers, who have in common that they set forth with glad feet and expectant faces toward that which lies beyond the knowledge and experience on their times. (Hunt, 1958, p. 1)

CHAPTER 7

RACHEL CARSON

On October 12, 2007, the Norwegian Nobel Committee awarded its peace prize to fervent environmentalist and former Vice President of the United States, Albert Arnold (Al) Gore, Jr. In the press release naming the politician the recipient of the highly vaunted prize, the Nobel Committee (2007) stated:

> Al Gore has for a long time been one of the world's leading environmentalist politicians. He became aware at an early stage of the climatic challenges the world is facing. His strong commitment, reflected in political activity, lectures, films and books, has strengthened the struggle against climate change. He is probably the single individual who has done the most to create greater understanding of the measures that need to be adopted. (p. 1)

While Gore's ability to raise awareness, particularly through his political and financial abilities to spearhead the production of *An Inconvenient Truth*, is truly noteworthy, he is far from the first to raise the clarion call to save the Earth from the ravages of man.

While serving as the vice president, a small picture of a woman that few would recognize hung on his office wall inside the Old Executive Office Building (Gore, 2007). The lady in this picture penned the following words which have guided Gore:

I pledge myself to preserve and protect

America's fertile soils, her mighty forests

And rivers, her wildlife and minerals,

For on these her greatness was established

And her strength depends.

The author of these words has deemed them to be the "conservation pledge" and would be the lodestone of her life. Gore (2006) credits this author in his best selling work, *An Inconvenient Truth: The Crisis of Global Warming*, for radically altering his understanding of humankind's impact on the planet.

> I first learned about the Earth's vulnerability to human hands from my mother. When I was fourteen, she read a book called *Silent Spring* by Rachel Carson. She thought its message that human civilization now had the power to seriously harm the environment was so important that she read it to my sister and me. The book's lessons made a huge impression on us. The way we thought about nature and the Earth was never the same again. (p. 10)

Five decades before Gore's much honored work for environmental causes, a little known writer and former federal government employee, Rachel Carson, wrote the words, "There was once a town in the heart of America where all life seemed to live in harmony with its surroundings.. Then a strange blight crept over the area and everything began to change" (Carson, 1962, pp 1-2). The preceding sentences opened Carson's seminal work, *Silent Spring*, a work that would attempt to radically alter the perception of humankind's relationship with the Earth.

In *Silent Spring,* Carson states the following is the position of humankind towards the planet we inhabit. "We still talk in terms of conquest. We still haven't become mature enough to think of ourselves as only a tiny part of a vast and incredible universe" (Carson, 1962, p. 5). Humans are in constant search of new and innovative ways to channel the natural resources of the Earth for our enjoyment while paying little regard to

the damages done to its other inhabitants or the environment in general. To ignore the consequences of one's actions on the larger ecosystem will eventually lead to devastating results for all including the human race.

Four decades following the initial publication of *Silent Spring*, Gore (1996) authored the introduction to Carson's work.

> *Silent Spring* came as a cry in the wilderness, a deeply felt, thoroughly researched, and brilliantly written argument that changed the course of history. Without this book, the environmental movement might have been long delayed or never developed at all. (p. 63)

Carson's work not only inspired the work of Vice President Gore but began the creation of a movement. Despite the change and controversy caused by her work, Carson has faded from the public consciousness.

Born in rural Pennsylvania in 1907, Rachel Carson spent her childhood exploring the countryside with her mother, a devoted nature lover. During her youth, Carson filled numerous notebooks with her observations regarding the beauty and wonder of the surrounding world. In 1925, Carson entered the Pennsylvania College for Women and would earn a bachelors of science in biology four years later. During her time at the college, Carson had the distinction of studying at Woods Hole Marine Biological Laboratory, the institution founded by Ellen Swallow Richards. In 1930, Carson matriculated to John Hopkins University to pursue a graduate degree in zoology. In 1932, she received her master's degree. Following graduation, Carson entered employment with the United States Bureau of Fisheries (later the United States Fish and Wildlife Service) as a researcher and writer. She would continue this work for the next twenty years.

While *Silent Spring* remains Carson's most comprehensive exploration of humankind's effect on the planet, her environmental work began decades before. In 1941, while she still served as a government employee with the Bureau of Fisheries, Carson's first book, *Under the Sea-Wind*, was published. Over the next fifteen years, Carson would complete two other major works, *The Sea Around Us* and *The Edge of the Sea*, and numerous magazine and journal articles. During this period, Carson's writings focused on sharing the beauty of the natural world that she found in her surroundings.

While the majority of Carson's writings prior to 1960 dealt primarily with the beauty of the East Coast of the United States, her second major work, *The Sea Around Us*, hints at what the future will hold.

> Drift ice in the Russian sector of the Arctic Sea decreased by a million square kilometers between 1924 and 1944... Activities in the nonhuman world also reflect the warming of the Arctic- the changing habits and migrations of many fishes, birds, land mammals, and whales. (Carson, 1954, p. 132)

While Carson was unable to identify the causes for rapid reduction in the Earth's polar ice caps, she suspected that the actions of humans were to blame. Carson understood the massive consequences of the melting of the polar ice caps- rapid climate change, the extinction of countless species, and disappearance of large quantities of land below the rising waters. While *The Sea Around Us* provides foreshadowing of future words that would flow from Carson's pen, it pales in comparison to the accusation she would level against mankind in the near future.

Sensing the impending disaster of DDT poisoning, Carson submitted a proposal to *Reader's Digest* in 1945 to write an article on the array of consequences of heavy

spraying of the insecticide. The proposal, due to pressure from the chemical industry, was hastily rejected by the monthly magazine. Carson placed her writings on insecticides on hold for over a decade. Consumed by completing *The Sea Around Us,* her employment at the Bureau of Fisheries, and the adoption of her grandnephew, Carson found little time to research the impact of manmade chemicals on the planet.

While Carson's crusade against DDT stalled, her advocacy for earth continued. In 1953, Carson campaigned against what she perceived to be environmentally unsound public policies of the Eisenhower administration. Appearing in the *Washington Post* letters to the editor, one of Carson's most pointed attacks included the following passage:

> For many years public-spirited citizens throughout the county have been working for the conservation of natural resources, realizing their vital importance to our nation. Apparently their hard-won progress is to be wiped out, as a politically-minded administration returns us to the dark ages of unrestrained exploitation and destruction. (Carson, 1953, p. 45)

The enemies made during this period would haunt Carson for the remainder of her life.

In January of 1958, Rachel Carson received a frantically penned letter from lifelong friend, Olga Huckins, the keeper of a bird sanctuary on the coast of Maine.

> The mosquito control plane flew over our small town last summer. Since we live close to the marshes, we were treated to several lethal doses, as the pilot criss-crossed over our place. (p. 1)

The planes dropped the highly effective insecticide, dichloro-diphenyl-trichloroethane (DDT). While the insecticide was effective in eradicating mosquitoes, it had an unintended effect also- the significant reduction in the Cape Cod bird population.

Since the discovery of its insecticidal properties in 1939, DDT became widely used to reduce mosquito populations. During the course of the Second World War, the United States military dropped millions of liters of DDT on Southeast Asia and North Africa. Following the conclusion of the conflict, the so-called miracle pesticide rapidly became the most widely used pesticide in American agriculture.

In September of 1962, the first printing of *Silent Spring* rolled off of the press. For the first time, the results of the advancements of humankind were questioned.

> One of the most alarming aspects of the chemical pollution of water is the fact that here- in river or lake or reservoir, or for that matter the glass of water served at your dinner table- are mingled chemicals that no responsible chemist would think of combining in his laboratory. (Carson, 1962, p. 44)

Carson referred to the contaminants pumped into the ecosystems and the water supplies as elixirs of death. The water testing and purifying systems in place at the time could not keep pace with the rapidly expanding array of chemicals continuously pumped into the environment without regard to the impact on the flora and fauna. Carson argued that the process of biological magnification, the increased concentration of harmful substances in organisms on higher levels of the food chain, was not well understood.

The lines connecting Carson and Ellen Swallow Richards are clear. In a similar vein to Richards, Carson concentrated her scientific talents on improving the human condition by reducing the damage humankind was inflicting on itself.

> Only yesterday mankind lived in fear of the scourges of smallpox, cholera, and plague that once swept nations before them. Now our major concern is no longer with the disease organisms that once were omnipresent; sanitation, better living

> conditions, and new drugs have given us a high degree of control over infectious diseases. Today we are concerned with a different kind of hazard that lurks in our environment- a hazard we ourselves have introduced into our world as our modern way of life has evolved. (Carson, 1962, p. 187)

While the agent of destruction had changed from bacterial to chemical, the enemy was the same- the rapid advancement of humankind without regard to consequences. In Richards' day, the rapid development of industry and the resulting population concentrations provided an environment ripe for the spread of bacterial-based diseases. In Carson's era, the battles against dysentery and cholera had been largely won in the United States, but a new and potentially more hazardous creation of humans threatened to destroy the delicate balance of nature. Carson continued the cry raised by Richards one hundred years before. We must forever remain vigilant and protect ourselves from our greatest enemy which is ourselves.

> Without Richards' work, Rachel Carson might never have had access to the knowledge she passed on to alert us. Two of the three schools from which Rachel Carson obtained that knowledge had felt the definite influence of the woman who founded environmental science: John Hopkins and Woods Hole Marine Laboratory. (Lear, 1997, p. 255)

Following the publication of *Silent Spring* in 1962, a mammoth attack, predominately orchestrated by the chemical industry and individuals within the government, commenced against the character and capabilities of Carson. The first wave of attacks proposed that a female, based on gendered stereotypes, was not capable of the rational thought necessary to make scientific claims.

> The sexism that greeted Carson and her sudden fame is not as blatant crudeness is striking. Many male readers, and certainly the scientific community, were reluctant to admit that a woman could deal with a scientific subject of such scope and complexity. One reader wrote, 'I assume from the author's knowledge that he must be a man.' (Lear, 1997, p. 206)

Those in positions of power hoped to dismiss Carson as an overemotional flake unwarranted of the legitimating effect of a Congressional hearing. According to Lear (1997), "By denigrating Rachel as nothing more than an emotional female alarmist, they hoped to win the public relations battle in the marketplace and avoid a legislative battle in Congress" (p. 429).

The first wave of attacks against Carson's work avoided any mention of the scientific merit of her claims. Only Carson's persistence and thorough research disallowed the cursory dismissal of her claims.

Carson's aggressive, persistent, and confident nature is typically associated with maleness.

> Culturally sanctioned typical female traits, in the current social system of science, are likely to put a woman at a disadvantage. These socialization patterns tend to distance women form the very characteristics that the social system of science rewards and reinforces: ambition, self-confidence, resilience, aggressiveness and competitiveness. (Barbercheck, 2001, p. 118)

Characteristics sought after in the males of the species entering science fields were seen as offensive and unseemly in this female.

In early 1963, President Kennedy, on the counsel of his national science advisor, read *Silent Spring.* After a four month study into the claims leveled by Carson, President Kennedy' Science Advisory Committee issued a white paper recommending a reduction in the use of pesticides until further studies could be preformed on the safety of the chemicals. The Congress, influenced by the power of chemical corporation lobbyists, refused to take immediate action. The course of events over the next several months would stall the inquiry into the impact of DDT and similar chemicals for nearly a decade.

While the book gave the young president pause to consider the rampant development of the United States and its near total disregard for the expansions impact on the environment, an assassin's bullet ended the rapid response proposed by Kennedy. Lyndon Baines Johnson's, a Texan with close ties to the oil industry, elevation to the presidency reduced the speed of response to the impending environmental disasters predicted by Carson.

In a rare interview given shortly before her death, Carson eloquently summed her position on the relationship between people and the planet.

> Man's attitude toward nature is today critically important simply because we have now acquired a fateful power to alter and destroy nature. But man is a part of nature, and his war against nature is inevitably a war against himself. We are challenged as mankind has never been challenged before to prove our maturity and mastery, not of nature, but of ourselves. (Carson, 1964, CBS interview)

As the power of humankind to manipulate the environment grew, understanding of the multitude of ramification's of playing God did not keep pace. The Earth was viewed as an object incapable of being damaged. Carson argued that this human-centric view would

eventually lead to the destruction of our planet as we know it and consequently the extinction of our species.

The work of Carson continued to have significant impact on governmental actions in regards to the environment. The National Environmental Policy Act was the most significant piece of legislation passed by the 91St Congress. The act mandated that projects funded by federal monies required a comprehensive environmental impact study to be completed before any works commenced. Additionally, in 1970, two other landmark pieces of legislation passed through Congress. The first created the Environmental Protection Agency (EPA), the first government entity solely devoted to ensuring the acts of humans would not inflict dire harm on the planet. The initial charter for the EPA included 5000 employees and a budget of $1.3 billion. Following quickly behind the EPA's creation, Congress authorized the Clean Air Act of 1970. While previous legislation had mandated pollution controls, the Clean Air Act of 1970 empowered citizens to file litigation against corporate polluters. For the first time, the average citizen of the United States could take direct action against corporate entities that polluted the environment by seeking injunctions and monetary damages from offending companies.

Carson's goal in writing *Silent Spring*, a government ban on the wide spread use of DDT, would not become a reality until eight years after her death. On December 30, 1972, the Environmental Protection Agency published a press release which included the following statement.

> The general use of the pesticide DDT will no longer be legal in the United States after today, ending nearly three decades of application during which time the

> once-popular chemical was used to control insect pests on crop and forest lands, around homes and gardens, and for industrial and commercial purposes. (Environmental Protection Agency, 1972, p. 1)

The end of the indiscriminate use of DDT had near immediate effects on the environment. Animal populations, mostly notably small fowl, began to rebound from the devastating effects of chemical poisoning.

The controversy surrounding the work of Rachel Carson has not ended. The attacks against her investigation into the health consequences of the chemicals pumped into our environment by humankind have continued. Senator Tom Coburn of Oklahoma, a physician with massive backing from the pharmaceutical and chemical lobbies, stated from the floor of the United States Senate:

> A strong argument could be made that no book in recent decades is responsible for more death and suffering than Rachel Carson's "The Silent Spring," a screed against DDT for killing birds and other wildlife. Her book, published in 1962, gave birth to modern environmentalism. In 1972, EPA responded by declaring (with little evidence) that DDT is 'a potential human carcinogen.' As a consequence of such junk science, this invaluable pesticide was banned in most countries around the world. (Coburn in Moore, 2007)

In recent years, attempts to honor Carson have met stiff resistance from the political right. Two attempts in the United States Congress to recognize Carson (the naming of the Springdale, Pennsylvania post office after her and a resolution honoring the 100th anniversary of her birth) were blocked on the grounds that her hysterical attack on the pesticide industry has caused widespread suffering. Coburn has led the battle against

preserving the memory of Carson. Coburn (2007), in a recent press release clarifying his position, stated: "Carson was the author of the now-debunked *The Silent Spring.* This book was the catalyst against the worldwide stigmatization against insecticides, especially DDT" (p. 1).

Coburn and his like have laid the blame for the worldwide malaria problem at the feet of Carson. According to this faction, the lack of a highly effective and inexpensive pesticide has allowed mosquito populations to explode. The resulting spread of malaria has been linked to nearly one million deaths annually. Those who wish to place blame on Carson have referred to her as a mass murderer.

The accusers of Carson fail to address the larger global travesties which have contributed to the substantial number of deaths caused by the disease. The near total lack of health care and very limited access to medications capable of mitigating the symptoms of the disease in the nations of Africa are major contributors to the epidemic. Placing the blame on Carson and other ardent environmentalists allows Western governments to avoid the issues raised.

While Carson argued for a reduction in the usage of DDT, the total ban of the pesticide was not her ultimate goal. According to Lear (2007):

> The truth is that Rachel Carson never called for the banning of DDT and never suggested in *Silent Spring* that pesticides not be used. Her research suggested that chemical pesticides were being used inefficiently, ineffectively, and indiscriminately. She worried about the chemical mixture that was being laid on the land and its ultimate effects on the soil, water, animal and human life- in the long run. (p. 1)

Carson worried about the lack of government oversight of the chemical industry and the general lack of safeguards to protect both human and non-human populations. Her call for testing has proven to be fortuitous for humankind. “Chemicals are disturbing hormone-controlled development, affecting gender, sex, and reproduction. And, we are now seeing, low doses are disruption enough” (Ray, 2007, p.12). The changes brought on by the work of Carson has led to more rigorous testing and oversight by governmental organizations. Without her call to awareness, the pollution of the environment would have continued unabated and unintended consequences would have damaged the future.

To the vast majority of humankind, science is seen as the search for the unadorned truth. Political and social forces have no bearing on the outcomes of scientific exploration.

> To avoid the threat of a mob rule that would make everything lowly, monstrous, and inhuman, we have to depend on something that has no human origin, no trace of humanity, something that is purely, blindly, and coldly outside of the City. (Latour, 1999, p. 13)

Science stands outside of humanity, or in the words of Latour (1999), “outside of the city.” The city is ruled by the lowly impulses of man. Science, located on a sacred mountain above the fray, is immune to the fallibility of man. Haraway (1997) refers to this as the “god trick.” Science is presented as if it were not performed within a context or situation. It speaks “authoritatively about everything in the world from no particular social location of human perspective at all” (Harding, 2004, p. 29). It is elevated above being manipulated by base human needs as if the work were performed on high. By

performing this god trick, scientists place their work on a higher plane of existence and therefore above reproach.

The inclusion of voices from the margins shines a light on the importance of subjectivity. The individuals viewing science from the margins are able to provide a perspective outside of the system. According to Ward (2004), "Marginal lives are those lives that are able to grasp not only the concepts which not only rule the lives of the ruling class, but that also stand outside those concepts and so are able to recognize them as mere conventions" (p. 31).

Views and voices outside of the mainstream provide unique perspectives with which to examine the knowledge created by the scientific community. It is the inclusion of voices from the margins that gives knowledge perspective.

> Carson was an outsider who had never been part of the scientific establishment, first because she was a woman but also because her chosen field, biology, was held in low esteem in the nuclear age. Her career path was nontraditional; she had no academic affiliation, no institutional voice. She deliberately wrote for the public rather than for a narrow scientific audience. (Lear, 2002, xi)

Carson's gender and position outside of the mainstream scientific community contributed to her unique perspective. She was able to see beyond the accepted viewpoints of the scientific establishment.

The impact of Carson's work can be found far and wide. From the writings of the obvious, such as Gore, to the more astounding, such as former Speaker of the United States House of Representative Newt Gingrich, the tendrils of Carson's work can be found. In the text which preceded his awarded winning movie, Gore (2006) states:

> Many people are convinced, mistakenly, that the Earth is so big, human beings can't do serious damage to it. Maybe that was true at one time. But not now. There are so many people on Earth and technologies have become so powerful that we are capable of causing serious harm to the environment. (p. 19)

The environmental impact of humankind is no longer being ignored by the rightwing of American politics. In 2007, Newt Gingrich, the former Speaker of the House of Representatives, penned *A Contract with the Earth*, a work entirely dedicated to the environment. In the opening of the text, Gingrich (2007) wrote of humankind's responsibility to the future of the planet.

> Whether we like it or not, humanity has assumed responsibility for the welfare of the earth and all the noble creatures that share it. The scale of human civilization, the volume of our economic activity, and the power of science and technology have made us shapers of much of the earth. The power to shape leads inevitably to a responsibility to wield this power wisely and carefully. (p.3)

Carson's contributions to biology and her massive impact on public policy have not been entirely forgotten. Prentice Hall dedicates one paragraph in their eleven hundred page *Biology*, an introductory high school text, to work of Carson.

CHAPTER 8

FINAL THOUGHTS: FADING VOICES

The work of Maria Mitchell was instrumental in building a foundation for the inclusion of women in the field of science. She was a pioneer in the fight for the education of women and in their right to be included in the field of science. She challenged the accepted viewpoint of her time that women were the lesser of the sexes and that they did not belong in the science lab.

> From the time she burst into national consciousness as the discoverer of Comet 1847 VI, she had been a model of what a woman, given the chance, could accomplish in science (Gormley, 1995, p.121).

Mitchell provided women the model of what a woman could accomplish in science. Her life and work was a contribution to the many women who followed her. Her students were exceptionally fortunate to have the opportunity to have such a mentor, but her influence was far beyond her classroom. She spawned a movement of women who went on to influence numerous others. One such student was Ellen Swallow Richards who saved countless lives with her work that led to the establishment of water standards and in the education of sanitary techniques for proper food preparation and cooking. She was a pioneer in the environmental movement and her work was a major contribution in its own right, but her work as an environmental advocate paved the way for other women to follow in her footsteps. The environmental movement influenced by the work of Rachel Carson was another step in the work of women challenging conventional beliefs and changing the course of history. She was able to communicate through her writing the

detrimental environmental impact of big science and industrial power to the general public. This was instrumental in sparking a broad environmental movement that had many followers. She was able to alert the public about the dangers of pesticides that they had previously not been privy to. The impact of such a movement is still being felt today. The work of Carson who died over forty years ago, is still having an impact on those she touched, including Al Gore, winner of the Nobel peace prize, environmental advocate.

On February 5, 1676, Isaac Newton wrote in a letter, "If I have seen a little further, it is by standing on the shoulders of Giants." Mitchell, Richards, Carson: These are Giants. They were not only foundation in each others' work but in paving the way for all women in science. It is these giants we must remember. They are only three examples of the many women who have changed how we live today.

In 1947, Marjory Stoneman Douglas' work, *The Everglades: Rivers of Grass*, highlighted the importance of maintaining each of the Earth's ecosystems not only for their natural beauty but for their part in supporting the health of the entire planet. Her defense of the system of waterways and wetlands served as the major barrier against public and private development of the area. She would dedicate the next fifty years of her life, until her death at the age of 108, to protecting the natural wonder of the Everglades.

In 1952, Gertrude Belle Elion developed 6-mercaptopurine, the first chemotherapeutic agent. Since her initial breakthrough, the development and use of chemotherapeutics has exploded. During her four decade career at Wellcome Research Laboratories, Elion's research produced drugs which treated gout, herpes, leukemia, and numerous other forms of cancer. Forty-five drug patents can be traced to her work. In 1988, Elion (with fellow researchers Sir James Black and George Hitchings) was awarded the Nobel Prize in

Medicine. In the presentation speech for the prize, Professor Folke Sjoqvist of the Nobel Committee (1988) stated that the research conducted by Elion led to:

> Well-proven medications which have stood the test of time over the past 15-35 years, and which remain today front-line agents for the treatment of a wide spectrum of illnesses. They also appear in the World Health Organization's list of so-called 'Essential Drugs', which demotes those medicines which should be available worldwide. (p. 1)

Dr. Alice Hamilton (1869-1970) spent her life protecting the health of the American worker. Hamilton's career spanned the industrial development of the United States. Her numerous studies led to increased occupational health standards across the nation. In 1919, Dr. Hamilton joined Harvard Medical School as the first woman faculty member in the history of the institution. Her work in the field of occupation and public health would continue both nationally and internationally (as a member of the League of Nation's Health Committee). In 1947, Hamilton received the Lasker Award, the most prestigious prize in American medicine, for her lifetime commitment to improving the health of the citizenry.

While we stand upon the shoulders of these Giants today, we have allowed them to fade from popular recognition. The women detailed above contributed significantly to the development and use of science in America, but their stories have all but disappeared. Women who could have clearly served as role models for future generations of scientists have been allowed to disappear into the mists of time. Without such role models, the various fields of science appear to be closed systems for women. The Women's Resource Center at the University of Maine (2007) finds:

> Women have traditionally been underrepresented in all mathematics and science career fields, as well as in other careers that require mathematics and science backgrounds. For many reasons, girls are often unintentionally directed away or discouraged from taking mathematics and science courses that will serve them later in their education or career fields. As a result, women find many academic and occupational doors closed to them. (p. 1)

The structural and social barriers to women's participation in mathematics, science, and engineering have had a profound impact on the growth of these fields in our nation. The need for scientists, engineers, and mathematicians in the United States has been well-documented. In 1983, the National Committee on Excellence in Education (NCEE) released *A Nation At Risk: The Imperative for Educational Reform.* The landmark report called for an increased focus on mathematics and the sciences in America's secondary schools and universities. Since the NCEE's call, numerous documents have been released reiterating the need to increase the pipeline of mathematics, science, and engineering talent in the United States.

Yet, despite the desperate need in our nation for highly qualified scientists and engineers, half of our population is steered away from these fields. The Commission on the Advancement of Women and Minorities in Science Engineering and Technology Development (2000) in the comprehensive report, *Land of Plenty: Diversity as America's Competitive Edge in Science, Engineering and Technology*, states:

> Now, more than ever, the nation needs to cultivate the scientific and technical talents of all of its citizens, not just those from groups that have traditionally worked in science, engineering, and technical fields. Women, minorities, and

> persons with disabilities currently constitute more than two-thirds of the U.S. workforce. It is apparent that just when the U.S. economy requires more SET workers, the largest pool of potential workers continues to be isolated from SET careers. (2000, p.11)

The lack of role models, both historical and current, for women in science perpetuates this issue. Women do not see careers in SET fields as realistic goals but as realms of study outside the competency of a *mere woman.*

Additionally, the stories reveal that the Truth of science is a fallacy. Science is rewarded a sacred position in America. "Science is absolute. If you do A and B, then C will occur. That rarely happens if you inject the inefficiencies of humanity into the process" (Baldacci, 1997, p. 497).

According to the National Academy Press' *National Science Education Standards* (1996):

> Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanation of the natural world. (p. 201)

Science is presented as the best of our knowledge because the knowledge received via the scientific establishment has been time-tested and withstood the attack of all. According to this line of thinking, science leads to the "best possible" explanation of the workings of the natural world through the rigor, procedures, and safeguards of the field. Latour (1986) states, "Science is seen as the opposite of the argument from authority. A few win over the many because truth is on their side" (p. 31). Science, as the search for Truth, is seen

as uncomplicated by the social and political workings of our society. If the few have found the Truth, it shall by its very nature rule the day.

Science is developed in a vacuum. The stories behind the exploration and creation of our scientific knowledge is unimportant. An examination of current science textbooks would lead one to believe that the above statements are true. While the humanness of science may be removed from textbooks, science will always be a human endeavor and subject to the nature of our species.

Science education is undergoing a period of dehumanization. The significant human endeavor of examining the world around us is being detached from the world. Attempting to remove the humanity from the teaching of the sciences is problematic. According to Egan (1986):

> We tend to teach mathematics and science as inhuman structures of knowledge, almost taking pride in their logical and inhuman precision. There are two problems with this approach. The first is that it is not true in any sense, the second is that it is educationally disastrous. (Egan, 1986, p. 30)

Science has not advanced in a clear and orderly fashion but has shown the fits and troubles of any human endeavor. According to Feyerabend (2007):

> The history of science is full of accidents and conjunctures and curious juxtapositions of events, and it demonstrates to us the complexity of human change and the unpredictable character of the ultimate consequences of any given act of decision. (p. 17)

To teach science as a system of orderly progression towards a final goal that has been predetermined, teaches a falsehood. In order to achieve the goal of science, an

understanding of the natural world to the fullest extent possible, the voices of all groups must be added.

Furthermore, the review of the stories of Mitchell, Richards, and Carson show the power of the system to create history which perpetuate the myths of the institution. In other words, the system is able to determine who will be Giants. In the case of these women and numerous others, the role played by women in the creation and expansion of scientific knowledge has been diminished or removed from the *official* history. According to Apple and Christian-Smith (1992), "What counts as legitimate knowledge is the result of complex power relations and struggles among identifiable class, race, gender/sex, and religious groups. Thus education and power are terms of an indissoluble couplet" (p. 2).

The educational process can be used as a form of thought control. Students are consistently battered with images that have a profound impact on the construction of one's world view. If the educational experiences portray the world, or a system in the world, as one allowing limited access to institutions to certain race, class, or gender, the institution is perpetuated in its current form and continues to act as a closed system.

Science has acted as a system closed to women for the last 150 years in the United States. While a select few women can operate in the research laboratories and academic institutions devoted to the sciences, their participation is often limited and inhibited by their sex.

The largest driver of the classroom curriculum presented to students is still the adopted textbook. According to Apple (1991):

> How is this legitimate knowledge made available in schools? By and large it is through something to which we have paid much too little attention- the textbook. Whether we like it or not, the curriculum in most American schools is not defined by courses of study or suggested programs, but by one particular artifact, the standardized grade-level-specific text. (p. 24)

The inclusion or exclusion of material from the textbook act to include or exclude particular forms of knowledge from the curriculum in the majority of classrooms. The text, as the authoritative version of knowledge, determines the stories of science which will be transmitted to the student.

While the number of women participating in all branches of science has increased significantly in the past four decades, equality with men has not been reached. The number of programs attempting to increase the participation of women in science, technology, engineering, and mathematics careers has increased significantly in the last thirty years, but unfortunately, the vast majority of these programs have been add-ons and not part of the formal school day curriculum. According to the American Association of University Women (2004):

> The majority of efforts in the past decade have been focused on out-of-school activities, which unfortunately have limited success in changing the regularities of schooling. As girls continue to show more interest and engagement in personal and extracurricular contexts, greater attention should be paid to infusing gender equitable STEM activities into the formal school curriculum. (p. 20)

While these efforts have expanded the opportunity for women to interact with science content it does not address the influence that the formal school curriculum has in its portrayal of science as a male field.

Science should be portrayed as a uniquely human endeavor.

The removal of personal stories of women and men engaged in the pursuit of scientific knowledge has dehumanized science. While the dehumanization of the pursuit of scientific knowledge has deleted the personal stories of both men and women from textbooks, this trend has had a disproportionate effect on women. The limited number of role models available to women in the real world (especially in physics and engineering) increases the importance of providing role models in text. The presentation of historical role models has been found to be highly successful in increasing women's participation in the sciences.

An examination of textbooks currently in use in elementary and middle school science classes finds the limited use of women historical role models. Women heavily involved with the development of the current state of scientific knowledge are not presented to the next generation of scholars.

Texts used in all fields of science should include the stories of a variety of individuals engaged in the pursuit of scientific knowledge. By expanding the word scientist to include all genders and races, the pool of individuals believing this path to being a valid and reasonable career choice is increased. The current lack of qualified scientist and engineers in our country makes this of paramount importance.

An examination of current science textbooks leads one to ask where are the scientists whose life work has been disjointed from them. Their well deserved recognition has been

replaced with lists of facts and formulas. The stories behind their discoveries not only add intrigue to the subject but also make the scientific process approachable. The success and failures that plagued the scientist in the pursuit of science discovery make science more human.

"Knowledge or information seen through, or by means of, human emotions, actions, hopes, fears, and so on, is not only more directly comprehensible but is also more engaging and meaningful" (Egan, 1992, p.86). Humanizing knowledge makes information to be understood more comprehensible. Dehumanizing of the field of science makes students less likely to identify with the subject. Personal stories are often included in such fields as history or literature, while substantially lacking in math and science.

> Mathematics and science are no less products of human emotions and intentions, and grasping those can be the surest way to grasping the meaning of mathematics and science. With textbooks that brought out the human aspects of these subjects, the work of teachers and students would be much easier (Egan, 1992, p. 106)

Science should be presented as a system of knowledge that can be and is flawed.

According to Kuhn, scientific systems of knowledge only acknowledge that which is compatible with current acceptance and disregards that which is not a part of the current paradigm. Only when confronted with overwhelming evidence that runs counter to the current paradigm will a change occur. By presenting the wealth of women's stories in the sciences, the current controlling paradigm, science is a field only suited to male characteristics and traits, becomes challenged. Eventually, if enough information is presented that runs counter to mindset, or paradigm, it will fall.

The inclusion of women in the history of science challenges the paradigm that all of the important scientific discoveries were made by men. The stories of women changing the course of science history are incompatible with this belief. These women challenge the belief of the fathers of science. Science rejects these stories for they challenge popular belief.

Science should be an inclusive system that values all voices.

Women's voices have long been absent from the sciences. The exclusion of these voices has not only harmed the women who have been pushed to the fringes of the fields but the general population as well. Harding (1991) states:

> Whether the social, political, or psychological benefits that men may have gained by discriminating against women in the past, the intellectual loss has never been justified. Invoking gender criteria when recruiting and advancing the best scientist and engineers works against their interests. (p. 160)

Generations of women scientists have not been able to make contributions to the advancement of scientific knowledge due only to their gender. We are all poorer for it. If the scientific community is dedicated to the exploration and explanation of the natural world, they should not exclude the voice of any of its inhabitants.

The stories of Mitchell, Richards, and Carson are examples of countless others who have been lost in the history of science. My research has uncovered numerous examples of women who made significant contributions to the field of science yet are virtually unknown to the general public. It is amazing that so many of their names have not been included in the common knowledge of science. It leads one to wonder how a field proclaiming to be the pursuit of truth could be so instrumental in burying the past. Those

who are commonly known in science are not necessarily those of most significance in importance to humanity. They are sometimes just the tales that are passed down in the mythmaking of the field. The tales of women are not as valued and therefore deemed less noteworthy. Perhaps the reality of the field is one that perpetuates the ills of its past and continues to believe in the importance of the fathers of science.

The curriculum lacks significant representation of women. This is a reflection of what the field has done to the memory of women.

A plaque of a human face is located in an old chemistry building on the MIT campus. It is black with age except for the nose. The common custom of rubbing the noses of old statues for luck still exists even when the face is unknown.

> Not one in a hundred of the keepers of tomorrow's environment knows the name or deeds of the person memorialized on the wall. Each, when asked, was unaware that the nose they rub for luck in life belonged to the person who first warned and worked against a polluted world (Clarke, 1973, p. 3).

Ellen Swallow Richard's work at MIT has been immortalized as a plaque used to amuse the students. Most of the students at MIT are oblivious about whom she was and her contributions to the field of science. Would she be remembered if she had been a man?

My research uncovered many surprising results. Information on Mitchell, Richards, and Carson was difficult to locate. Numerous searches located only a handful of books on them. Many of the texts were out of print or only located in juvenile literature. Several books were library copies with the word 'DISCARDED' stamped inside. I thought about all the wonderful accomplishments that these women made to the field of science, how they dedicated their lives to make our world a better place to live, and how unfair it is

that their memories are being discarded. The difficulty that I encountered in finding information on them reflects the lack of importance science history has placed on them. In time, they may be completely forgotten. If the science curriculum continues to perpetuate the vision of only men being important in science, we are only generations away from these women and others passing into oblivion.

I would like the science curriculum to tell the lesser known stories of the women who had an impact on the field but were marginalized and excluded from the recognition they deserved. Like the reconceptualist movement, I seek to change the field of education to move away from the answers toward the questions. Why aren't there more stories of women scientists in the science curriculum? Has the science curriculum contributed to the lack of women interested in the field? Can reformation of the curriculum bring change to the gender inequality in female interest in the field? It is this kind of disruption of the science curriculum that may be needed.

> This kind of disruption is political because, although it seems like an "inconvenience" to those who are interested in maintaining the status quo of developing curriculum, to those who wish to disrupt it, it is to open up a "line of flight" in power and meaning for the use of those who are marginalized and excluded. (Reynolds & Webber, 2004, p. 5)

The marginalized women's stories such as Mitchell, Richards, and Carson give a different perspective on the history of science. In examining these stories one opens up a "line of flight" from the accepted curriculum and approaches science history from a marginalized perspective. It is this freedom from the mainstream curriculum that allows us to soar into a realm of understanding. I would like the stories of these and other

marginalized individuals to enter the sacred realm of textbook knowledge so that others could share my amazement at the contributions of the great women in science.

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